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ABSTRACT

This discussion of the status and future of science education grew out of the need for a more recent document to succeed "School Science Education for the Seventies." The document is composed of three main parts. The first part addresses the aims of science teaching, looking at the general principles as stated in the past, the current view, and the need for flexibility in the future to accommodate individual needs. The second part of this paper discusses the present situation of science teaching in the United States, including sources of satisfaction and hope such as the new curricula and inservice education, and areas of concern such as population trends, funding, and accountability. Finally, the third part presents recommendations for the coming years in the areas of curriculum development, improvement of teaching, the encouragement of women and minority students, and trends in Federal support and their implications for science education. (BB)

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SCIENCE EDUCATION:
ACCOMPLISHMENTS AND NEEDS

A WORKING PAPER

NATIONAL SCIENCE TEACHERS ASSOCIATION
1742 Connecticut Avenue, N.W.
Washington, D.C. 20009

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FOREWORD

THE ERIC SYSTEM

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In addition, each clearinghouse works closely and cooperatively with professional organizations in its educational area to produce materials considered to be of value to educational practitioners. The ERIC Clearinghouse for Science, Mathematics and Environmental Education has worked cooperatively with the National Science Teachers Association on this publication. ERIC helped fund the conferences to produce the document and is publishing the working paper which has resulted.

THE WORKING PAPER

SCIENCE EDUCATION: ACCOMPLISHMENTS AND NEEDS is an evolutionary document. It grew out of the need for a more recent document to succeed School Science Education for the Seventies, produced by the National Science Teachers Association's Curriculum Committee (as this committee existed under the organizational pattern at that time). A series of meetings and drafts of the paper preceded the development of the present document. Persons representing the various affiliated groups were asked for reactions as well as for the identification of relevant materials. Some of the individuals involved and their activities are identified in the preface of this paper.

The present document is a result of committee action and the views contained in it reflect no single individual's perceptions. Persons seeking an exhaustive list of references should be assured that no statements are made for which document is not available even if not all sources which could be cited have been included.

ERIC invites comments, ideas about the future of science education, and reactions to this working paper. Such material should be sent to the National Science Teachers Association, 1742 Connecticut Avenue, N.W., Washington, D.C. 20009. It is hoped that a future document could be prepared which would extend this working paper and make use of the ideas and reactions submitted by others.

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PREFACE

On March 18, 1976, the Board of Directors of the National Science Teachers Association approved the appointment of a committee to prepare a document on science education in the 1980s. As a first step, a conference was held from June 5th to June 7th at the Skidaway Institute of Oceanography in Savannah, Georgia, with 25 persons participating. Their recommendations constituted the first step in preparing the present report. Thereafter, the report was developed by a committee chaired by Mary Budd Rowe; its members were John M. Akey, Richard C. Clark, James V. DeRose, Linda K. Froschauer, Sylvia K. Shugrue, Robert L. Silber, and Doris A. Trojcak. The committee wishes to thank the many persons who helped with the various stages of the report and whose suggestions and formulations were so valuable to the development of this report. The names of these persons appear in Appendix II.

Dr. James Hall and Dr. Minda Rae Amiran served as Research Editors for the paper. Dr. Gerald Skoog and Dr. Vincent Lunetta contributed to the final editing.

Self-examination is a continuous process. The present document is not intended to stand for all time, or even for a period of so many years. On the contrary, it must undergo continual examination and revision, as conditions change in the world of science teaching, in American education, and in our lives. The paper should be read with the understanding that it represents our clearest assessment of the accomplishments and needs of science teaching at the present time.

SCIENCE EDUCATION: ACCOMPLISHMENTS AND NEEDS

Introduction

Any examination of the goals, priorities, and achievements of science teaching in the United States must begin with a recognition that the teaching of science occurs in an educational system within a society that has changed drastically in a short period of time. Many problems exist in that society that influence the conditions in which the teaching of science occurs. The rate and nature of change, as well as the problems facing the nation and the world, also influence the outcomes that can be expected from instruction in science. Certain of these problems are of such importance to the educational process that they frame the discussion of this document.

Of the many changes that influence schools and, thus the teaching of science, none has been more important than changes in the structure of the family. There is growing evidence that family structure in the United States is eroding and becoming weaker. Today, one of every six children in the nation is living in single-parent families. The number of single parents has been increased by a divorce rate that has tripled since 1950 and by a growth in illegitimacy. The single parent is usually female and working full time. Over 50 percent of women with school-aged children are employed. Because of this and other factors, parents appear to be spending less time with their children. Child abuse is increasing. In many divorce cases, neither parent wishes to take custody of the children. Extended families, which have been a traditional source of assistance to parents and children, are much less common than in the past. These and other changes in the structure of the family have thrust new responsibilities on the schools and society.

The weakening of the family structure has been accompanied by increasing problems among youth. Among the most serious problem is the prevalence of youth crime. Youths aged 10 to 17 commit more than half of all serious crimes in this nation. The rate of juvenile crime has risen twice as fast as that of adults since 1960.¹ One report indicated that "Many youngsters appear to be robbing and raping, maiming and murdering as casually as they go to a movie or join a pickup baseball game."² This crime is spilling over into schools and science classrooms. Each year an increasing number of teachers are assaulted. Vandalism and destruction grow. The National Association of School Security Directors estimated that in a recent year more than \$590 million was diverted from annual education budgets because of school vandalism.³

The annual suicide rate among white youth between the ages of 15 and 19 increased 171 percent from 1950 to 1975 while death by homicide among white males aged 15 to 19 has increased by more than 200 percent since 1959.⁴ Drug and alcohol usage and abuse among youth have been widespread. Venereal disease and an increase in the rate of illegitimate births among youth are also growing problems. Other changes and problems exist that influence how students think, feel, and act as they spend time in school.

Undoubtedly the environment which these facts reflect influences the motivation and performance of students throughout the school system. Has the decrease in science achievement scores as measured by the National Assessment of Educational Progress in 1969-70, 1972-73, and 1977 resulted largely from such external forces or have the curriculum and instruction deteriorated? If external forces are responsible for all or part of the decline in science achievement scores, can changes in the teaching of science result in improved achievement?

The assumption that improvements in the teaching of science will make a difference in the lives of students and the quality of society must be made. Furthermore, it must be assumed that students and teachers can be stimulated and encouraged to become involved in the study and teaching of science. Nevertheless, the assessments and recommendations of this working paper must be analyzed and read realistically in terms of the problems facing both the American schools and society. The teaching of science occurs in a vastly complex social and educational environment where many forces exert an influence on what is possible to achieve in a classroom.

THE AIMS OF SCIENCE TEACHING

General Principles as Stated in the Past

During the past few decades, there has been general agreement on the general principles that provide directions for the teaching of science. The Thirty-first Yearbook of the National Society for the Study of Education, A Program for Teaching Science, published in 1932, proposed that science curricula should be organized around the principles and generalizations of science.⁵ The writers of this yearbook proposed the study of the "large truths of science" because they "have within them the greatest potentialities for influencing thought and action."⁶ Scientific attitudes were also to be stressed. In 1964, a respected science educator contended that the Thirty-first Yearbook "was destined to exert more influence on the teaching of science in American schools than any other publications."⁷

In 1936, the Committee on Policy and Research of the National Education Association formulated the "Statement of Principles Basic to Instruction in the Natural Sciences" in which science was described as "a method...of arriving at organized, tested, and dependable knowledge" to be taught with a view to enhancing "the student's ability and will to participate intelligently in effecting progressive and continuous improvement, both of himself and of his material and social environment."⁸ Other committees of the 1930s also defined curriculum content in terms of principles and generalizations thought to have value in meeting the needs and problems of students.⁹

The Forty-Sixth Yearbook of the National Society for the Study of Education, Science Education in American Schools, in 1947 emphasized the importance of stressing functional concepts, instructional

skills, problem-solving skills, attitudes, appreciations, and interests.¹⁰ The committee endorsed the practice of including the "big ideas" of science as advocated in the Thirty-first Yearbook in 1932. The committee supported these generalizations and principles as being "true, essential, and enduring" and as "drives to action."

Rethinking Science Education, the Fifty-ninth Yearbook of the National Society for the Study of Education published in 1960, emphasized that students should attain a useful command of science concepts and principles.¹¹ The importance of the attainment of the attitudes and modes of reasoning which lead to the organization and application of concepts and principles was also emphasized. Thus, in 1932, 1947, and 1960, NSSE Yearbook Committees all agreed that the "big ideas" and central concepts of science were important to the science curriculum. They also represented the views of most science educators during this period.

Theory Into Action,¹² a 1964 publication of the National Science Teachers Association (NSTA), gave further support to the strategy of teaching the concepts and "big ideas" of science as well as teaching science as a process or a method. The writers of this document stated that "Education in the sciences must be based upon the kind of information that has survival value and strategies of inquiry that facilitate the adoption of knowledge to new demands."¹³ In a 1971 position statement, NSTA, in emphasizing the survival value of science, stated that the major goal of science education was "to develop scientifically literate and personally concerned individuals with a high competency for rational thought and action."¹⁴ Scientific literacy was to be achieved through the "development of attitudes, process skills, and concepts."¹⁵ In this position paper, a "scientifically literate" person was defined as one who:

- uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment
- understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories
- distinguishes between scientific evidence and personal opinion
- identifies the relationship between facts and theory
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare
- understands the interrelationships between science, technology and other facets of society, including social and economic development
- recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates

- has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others
- has a richer and more exciting view of the world as a result of his science education
- has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and its excitement of inquiry
- continues to inquire and increase his scientific knowledge throughout his life¹⁶

Overall, during the past few decades the emphasis has been on the teaching of the concepts and the process skills of science. There has been increased recognition that the knowledge, attitudes, and methods of science must play an important role in coping with and resolving the many problems and dilemmas in contemporary society.

General Principles Today

The general principles and aims for the teaching of science presented in the preceding section of this working document seem appropriate as society moves in the 1980s. Society needs scientifically literate citizens more than ever as science-related problems surface, accumulate, and demand resolution. Decisions regarding the sources and use of energy are complex. Research (both actual and possible) in molecular biology has evoked much debate and controversy. Decisions on nuclear energy and weapons are controversial and complex. The need for population control and increased food production continue to exist. Medical breakthroughs and changes in life styles are needed to alleviate the world's population of many diseases. The conditions to be inherited by the citizens of the 1980s make it essential that this nation educate superior scientists, engineers, and technicians as well as a general populace that understands and utilizes the knowledge, methods, and attitudes of science.

Thus, contemporary science programs must provide a broad, general education in science for all citizens and a more specialized scientific education for individuals who will become scientists and technicians. A broad general education in science should provide every person--child or adult--basic knowledge about the natural world, an understanding of the methods of scientific investigation, especially of the relationships between theory and evidence, an appreciation of the limits of scientific inquiry, and some knowledge of the ways in which scientific research can be used to improve daily life. It should also provide an awareness of social and moral problems which may arise in the practice of scientific research and in technological applications in the world. More specialized education additionally would provide science-prone students with more sophisticated knowledge and experiences in traditional and emerging scientific fields.

Teachers, parents, students, and policy-makers should not view a curriculum for the talented students in science as elitist. These students may or may not be more academically talented than students with different interests and needs. However, they do have special interests and goals which schools must accommodate and nurture if schooling is to help individuals develop their special interests and abilities. Too often, the talented student in science has been discriminated against through neglect. Science curricula must provide opportunities for meaningful experiences for all students regardless of their interest and ability in science.

General Principles and Individual Differences

The National Science Teachers Association is firmly committed to seeking and promoting education in the sciences for everyone. Science educators repeatedly have expressed concern that women, blacks, and members of certain ethnic minorities have been discouraged or prevented from gaining a sound education in the sciences as well as the opportunity to discover and nurture their own abilities in the sciences. Artificial barriers that prevent equal access and opportunity to study science should be obliterated. However, equality of access does not imply and should not result in a uniform curriculum to be experienced by all. A variety of teaching materials and methods must be developed so that real differences in the interests and needs of students can be accommodated and nurtured.

Individuals differ in many important ways that influence how science may be taught and learned. The work of Jean Piaget and others has provided evidence that individuals vary in their level of cognitive development which, in turn, influences how certain problems in science can be approached and understood. Students of a specific age are at various stages in their thinking and this fact necessitates different approaches in teaching science. Failure to recognize and to respond to these differences in cognitive development has resulted in frustration, fear, and failure for some students. For others, the result has been boredom and insufficiently challenging encounters with the phenomena of science.

Researchers in education and psychology have identified many other ways in which the abilities and tendencies of individuals may vary. Profiles based on verbal, numerical, spatial, and reasoning abilities have been developed to illustrate differences in individuals. Other data have been used to categorize individuals on characteristics such as extroversion or introversion, sensing, or intuition, thinking or feeling, and judging perception. Individuals in one category apparently perceive the world differently from individuals in another, and these differences in perception influence the student's interest and approach to specific problems or areas in science.

Benjamin Bloom,¹⁷ an advocate of mastery learning, has been contending that nearly all students can learn what is necessary to learn if schools approach instruction sensitively and sensibly. He has argued that there are not good learners and poor learners but rather

fast learners and slow learners. He has argued for instruction that would accommodate various rates of learning as well as the variation in entry levels of knowledge, skills, and attitudes that a student brings to a specific learning task.

Overall, there are many data pertaining to how students learn. Enough is now known to justify the development and existence of different approaches to the teaching and learning of science to accommodate the different skills and needs of individual students.

General Principles and Continuous Revision

Curriculum development and revision is a continuous process. The quest of discovering the "best" teaching materials, the "best" teaching methods, and the "best" preservice and inservice teaching procedures must be continuous. Science is a dynamic body of knowledge that continues to expand as inquiry into various aspects of the universe continues. The impact of individual efforts of inquiry varies, but collectively the efforts continue to push back the frontiers of science. In doing so, new knowledge accumulates and the meaning of old knowledge changes. As a result, the development, dissemination, and implementation of appropriate teaching materials and methods in science must always be a continuous and ongoing process. Changing social circumstances, different national priorities, and new information from research in psychology and education also influence the content of the science curriculum and methods of teaching.

As new knowledge changes current views of the nature of society, science, and learning, there must be a continual reassessment of the aims of science teaching. Some of the aims of today will endure into the future. Others will be interpreted with different emphasis while still others will become obsolete and discarded. Inasmuch as curricula should be based upon the goals of instruction, changes in curricula should follow evolving goals.

THE PRESENT SITUATION OF SCIENCE TEACHING IN THE UNITED STATES

Sources of Satisfaction and Hope

New Curricula

Achievements in curriculum development over the past 20 years have been exemplary. In the many projects supported by the National Science Foundation and other sources, scientists, science teachers, and science educators collaborated to develop a wide variety of curriculum materials for students enrolled in kindergarten through college. These curriculum projects were influenced by persons in psychology and education as well as by practicing scientists. Concern that science curriculum materials should depict the nature of science and contain contemporary information certainly influenced the directions and development of the projects. As a result, the processes of science were accorded priority and student

inquiry was emphasized. Laboratory investigations were developed so students of many ages could have actual experiences with various aspects and phenomena of science. Broad conceptual schemes were emphasized because of their more enduring significance in a changing world where the half-life of facts is notoriously short. Changes in content and approach were accompanied by a variety of teaching aids and materials. Films, film loops, and filmstrips provided students with needed vicarious experiences. Comprehensive teacher guides, laboratory manuals, examination booklets, and laboratory kits provided teachers with needed assistance. The new projects also influenced the publishers of existing science textbooks and, as a result, many of the descriptive, fact-oriented textbooks of the 1940s and 1950s began to change. Explanations of obsolete technology, dogmatic explanations of scientific method, and laboratories emphasizing verification or confirmation have become less common as traditional textbooks have been revised during the past 20 years.

As a result of the emphasis on curriculum development in the sciences, curricula today are more representative of current knowledge in the sciences than was the case 20 years ago. Furthermore, a greater variety of curriculum materials now exists. Modern technology is examined in some programs. Materials in environmental education have proliferated. Interdisciplinary approaches have become more popular. Modules or short units that the teacher can arrange to suit local or individual needs have been developed. Materials appropriate for individually paced or small group study are available. As a result, there is today a greater variety of curriculum materials than there was two decades ago to meet the needs of both science-prone students and those who are less academically-oriented.

As change has occurred and choices broadened, patterns of adoption of science curriculum have been influenced. In 1971, 27 percent of all elementary schools in the nation were using at least one of the new curriculum projects.¹⁸ Over half of the nation's junior and senior high schools were utilizing some of the materials developed by the NSF-sponsored projects.¹⁹ Environmental education existed in some form in 80 and 63 percent of the elementary and secondary schools, respectively.²⁰ (The NSF-sponsored projects have influenced a larger number of students than these statistics suggest inasmuch as these curriculum materials have been more widely used in larger schools than in smaller ones.)

New science courses and laboratory programs in higher education have also begun to emerge during the past two decades. The directions and nature of the revisions have been influenced by the same forces that brought about changes in the secondary school science curriculum. The reconstruction of the collegiate science curriculum is also very important if the general education needs of a scientifically oriented population are to be satisfied. Furthermore, revisions in the science curricula of higher education institutions must continue so that the preparation of science teachers and other professionals will be appropriate for the demands of society.

Inservice Education

Satisfaction and hope accrue from the fact that a sizeable proportion of the nation's science teachers has been involved in inservice and continuing education. A 1971 survey²¹ reported that about one-fourth of all elementary teachers were working toward a master's degree whereas another one-fourth had already earned such a degree. Fourteen percent of the elementary science teachers had attended an NSF-sponsored workshop and two-thirds reported involvement in some type of inservice education program or activity. Similarly, one-fourth of all junior and senior high school science teachers were working toward a higher degree. More than one-half of these teachers had participated in NSF funded institutes. Over 50 percent of the secondary school science teachers had participated in NSF Summer Institutes whereas 9 percent were involved in Academic Year Institutes. Many had attended both types of institutes as well as NSF COOP Inservice Programs and NSF Research Institute Programs.²²

The 1971 report²³ also indicated that other sources of inservice education were utilized. About 36 percent of the schools had utilized city or county supervisors for inservice activities. Twenty-five percent of the schools had used state supervisors and personnel from higher education for both workshops and curriculum development projects.

A variety of facilities and programs for inservice training, most of which are federally funded, now exists. General educational information centers, special education centers, teacher centers, school study councils, education libraries connected with teacher-education programs, ERIC Clearinghouses, regional laboratories, and NIE Research and Development centers have all played a part in the expansion of inservice opportunities. It is difficult to determine the use that science teachers make of these facilities and services, but undoubtedly their availability has served to strengthen the skills of science teachers.

Journals in education and in the various disciplines in science have been important in the continuing education of science teachers. Many state affiliates of NSTA publish journals and/or newsletters which are forums for science teachers to exchange ideas for units and teaching strategies that have a local or regional orientation. Journals and publications such as the New Jersey Associates for Environmental Education Newsletter, the Pennsylvania Clearinghouse on Methodology in Elementary Science, South Carolina Wildlife, and the New York State Department of Environmental Conservation's The Conservationist represent some of the many special interests within the profession. An abundance of national journals concerned with education are available also. The Current Index to Journals in Education lists approximately 700 journals. The Science Teacher, Journal of Research in Science Teaching, Science and Children, School Sciences and Mathematics, Journal of College Science Teaching, American Biology Teacher, Journal of Environmental Education, Journal

of Chemical Education, Chemistry, Physics Teacher, American Journal of Physics, and Journal of Geological Education are of special interest to science teachers. Many other journals and publications that are of special value to science teachers as well as to teachers of other disciplines exist.

Overall, science teachers have varied opportunities for continuing education, inservice experiences, and self-improvement activities. However, these opportunities must be expanded and intensified as the rapid pace of change requires that science teachers remain knowledgeable in the fields of science they teach. Also, science teachers must be kept informed of new curriculum materials in science as well as new practices and knowledge in education.

Areas of Concern

Population Trends

Declining birth rates have decreased school enrollments in many areas of the nation. Elementary schools have been closed and sometimes demolished. A similar fate awaits many secondary schools as a 13 percent decrease in public secondary school enrollment is forecast for the period 1973-1983.²⁴

This decline has resulted in the notion that there is an excess of teachers nationwide. However, in certain areas where population growth is increasing, there are shortages of teachers. The demand for science teachers remains high in several areas of the nation. Overall, it is difficult to obtain precise information on the magnitude of the problem and on differences by areas of specialization.

Planning for classroom space and future staffing patterns is made difficult because the decline in population will not be uniform. An "echo baby boom" is predicted to occur when the daughters of the World War II "baby boom" reach their most productive child-bearing years. If these predictions are correct, elementary school populations will increase in the late 1980s with increases in secondary school and higher education following. If this "accordion-like" demand for classrooms and teachers continues, solutions other than discouraging individuals from selecting teaching as a profession and the razing of unused school buildings must be found.

Despite the decline in student enrollments, the diversity of students within many classrooms is increasing as a result of mainstreaming, desegregation, immigration patterns, and pressures for youth to remain in school. The increased diversity of students has created a need for a greater variety of school experiences and more individualized instruction. In many areas of the nation, classroom space and the number of teachers available make it feasible to lower teacher-pupil ratios and intensify efforts to create educational environments that are more adaptive to the wide range of student needs and abilities found in most schools. Despite the feasibility

of this proposition, taxpayer resistance stands in the way. It seems unlikely that citizens will pay increased taxes, allow school budgets to increase, and urge legislatures to appropriate more money for schools when school enrollments continue to decline, inflation continues unabated, and dissatisfaction with student performances on certain standardized tests and competency examinations mounts. Based on the difficulty some cities and states have had in obtaining sufficient funds to keep schools open the past few years, this view cannot be considered pessimistic.

Stabilized or declining enrollments and budgets can lead to a stable faculty. Currently, there is much concern that the low turnover in faculties will result in stagnation as fewer new teachers will be hired and, as a result, the flow of new ideas and approaches into schools will slow down. This has become a particularly serious problem in higher education where enrollments and budgets are declining and few new faculty are hired. Furthermore, fewer students are pursuing graduate programs and this reality may well weaken the research programs of many universities. Many researchers in science regard this to be a serious and urgent problem.

The Decline of Funding for Science Education

Federal support for education increased from \$5.4 billion to \$12.3 billion from 1963 to 1967.²⁵ Annual expenditures on education increased from \$45 billion in 1965 to \$80 billion in 1970. In 1960, 5.3 percent of the gross national product went to education. In 1970, this percentage increased to 7.7 percent.²⁶ In the 1960s, federal funds became available through the Vocational Education Act, the Mental Retardation Facilities Act, the Elementary and Secondary Education Act, and the Higher Education Act. The National Defense Education Act in 1959 authorized funds for graduate study grants and purchase of teaching materials for science and mathematics. Meanwhile, the Assistance to Education Act made available funds for school districts with large numbers of students from families with low incomes. Collectively, the funds made available from these various congressional actions and the increased level of spending did much to eliminate some deficiencies and problems in schools.

Since the late 1950s, the National Science Foundation has been an important source of funds for curriculum development and continuing education. Science education has benefited greatly from these funds. Innovative and exemplary science programs have been developed for elementary, junior high, and senior high schools. Inasmuch as these programs required different teaching behaviors and skills, the National Science Foundation (NSF) supported many programs for the preservice and inservice education of teachers. NSF funds were also used to improve graduate programs in science education centers in colleges and universities. Special activities and programs in science for talented senior high school students were created throughout the use of NSF funds. As a result of the increased activity in science education, many of the nation's school

districts found it advantageous to employ science supervisors. The services resulting from the employment of the supervisors led to more improvement in the science curricula of schools. Overall, the funds from NSF did much to bring about reform in science curricula in the late 1950s and 1960s.

During the late 1960s, public support for education began to wane. The nation passed through troubled times in the 1960s and, even today, it is difficult to assess the lasting effects of the upheavals of those years on the nation's schools, governments, families, and society. Assassinations; massive protests against American involvement in Vietnam; turmoil resulting from civil rights movements; the disappearance of large number of youths from their high schools, colleges, and homes; increased use of drugs; draft evasion; disillusionment with government and the due process; and countless other events and changes rocked the American people. As cherished values and norms were being weakened and discarded, many citizens blamed the schools and looked to the schools to restrain or halt the nation's ferment. About the same time, evidence began to appear that student achievement in reading and other areas was less than expected and desired. In some school districts, such as in many inner city schools, program deficiencies were identified. In both cases, citizens accused schools of lowering standards and utilizing social promotions too widely. Thus, as the 1960s ended and the 1970s progressed, disillusionment with the schools tended to increase.

Science and technology have also been targets of disillusionment during the past decade. Many concerned citizens believed that science had failed the nation. Critics complained that because of science, awesome weapons had been invented and man had gone to the moon, yet millions of human beings were starving and the quality of the environment was deteriorating. As the esteem of science and technology declined, the popularity of astrology and other forms of pseudo-science increased. The anti-science mood of the nation contributed to a decline in federal funds for scientific research and a drastic reduction in the programs of NASA. Due to this reduction in funds, thousands of scientists were unemployed. The anti-science mood of the nation and the declining opportunities in science made careers in science and technology less attractive to the nation's schools and universities declined and public support for science programs was weakened.

The loss of public confidence in science and in public education was accompanied by a decline in certain federal appropriations for education. Exact figures for government spending on science education do not exist. However, certain National Science Foundation (NSF) data illustrate trends.²⁷ According to NSF, total federal obligations of research and development in education decreased from \$214.2 million in 1973 to \$173.5 million in 1974 to \$157.8 million in 1975. This represented a 19 percent decrease from 1973 to 1974 and a 9 percent decrease from 1974 to 1975. The actual decreases were even larger if the 6 percent annual inflation rate during this period is considered. Within these figures, NSF estimated that federal support

for university research in sciences fell 8 percent in constant dollars between 1974 and 1975, and the support for research in science education fell 16 percent in actual dollar sums. The National Institute of Education (NIE) argued that NSF used a definition of research that was too narrow and excluded dissemination and utilization activities, among others. The National Institute of Education (NIE), in utilizing the estimates of the Office of Management and Budget (OMB), depicted federal expenditures of \$414.2 million, \$429.8 million, and \$552.6 million in 1974, 1975, and 1976 respectively.²⁸ The OMB estimates contained funds allocated to the Public Health Survey and the Departments of State, Justice, and Treasury for various programs with secondary education goals. According to OMB data, NSF received \$35 million in 1974 and \$31.3 and \$28.6 million in the two succeeding years. The National Institute of Education reported expenditures for Research and Development Centers, Regional Educational Laboratories, and Educational Resources Information Centers had declined from \$42.5 million in 1973 to \$37 and \$33.9 million the next two years. During the same period the number of Research of Development Centers fell from 12 to 10, the Regional Laboratories from 11 to 7, and the ERIC Centers from 18 to 16.²⁹

Federal support for education may not decline sharply in the future. However, the patterns of past support are changing. The emphasis on curriculum development and reform is declining. New strategies for improving education are emerging. The period in which curriculum development was emphasized was a good time for education in the sciences. If education in the sciences is to be improved through federal support, it must be recognized that the ways of the 1960s are a legacy of the past and will not be a part of the 80s. New strategies for improving education in the sciences must be proposed and tested.

The Decline of Science in the Curriculum

There is growing evidence that parents, taxpayers, policy-makers, and students do not view the study of science with the same esteem as did their counterparts in the 1960s. The focus of public education is changing in response to the public's demand for improved teaching and learning in the areas of reading, mathematics, spelling, and writing. Time previously spent on instruction in science is being shifted to other subjects in many elementary schools. Some secondary schools are also using time formerly allocated to science for reading or other basic skills.

Enrollment in science courses in some schools has declined as a result of changing priorities of society, greater flexibility in diploma and degree requirements, changing students needs, and declining student population. However, disillusionment with science and technology, traditional courses with undue emphasis on classical science, and a tightening job market in some areas of science also have probably contributed to the decline in science enrollment in many schools. In some schools, the study of science has been made less attractive

because of the lack of funds to purchase laboratory materials and supplies. Teachers report that in some schools there are not enough science textbooks for each student.

In addition to declining enrollments in science, scores on the achievement tests in science administered by the National Assessment of Educational Progress (NAEP) have continued to decline since 1969. A continued decline in verbal aptitude as measured by the Scholastic Aptitude Test (SAT) has concerned science teachers, also.

The decline in enrollments in science courses and science achievement must be reversed. The nature of contemporary society demands a population that understands science. As a result, new efforts at curriculum development must emerge and be supported. New knowledge concerned with learning theory and motivation must be applied. Different teaching and learning strategies must be explored. Large sums of money are not and probably will not be available to support these efforts. In the end, progress in solving these problems will be made primarily through better use of existing financial, physical, and human resources.

Problems with Accountability Procedures

As a result of increased concern with school budgets and the public's preoccupation with student performance in certain basic academic areas, the use of accountability procedures has spread and intensified. Science teachers have been required to determine the dimensions of scientific literacy and minimum competencies for courses and course sequences. Also, science teachers are being required to design evaluative procedures to determine whether students have the minimal competencies specified.

The specification of and measurement of basic competencies in science have been difficult tasks. There are several questions that are difficult to answer. Who should determine what competencies are required? How should these competencies be determined? What level of achievement represents competency? Who establishes the levels or standards of achievements? Will "teaching for the tests" become common and prostitute the science curriculum? What happens to students who fail the examinations? Will special instructional opportunities be available for students who fail? Will the time spent on various learning tasks vary from student to student? Should the school and teacher be held responsible for student failure and success? How is student achievement influenced by factors such as home environment, community conditions, and various social forces? If a majority of students in a given class or school does not attain the minimal competencies, has the school science budget been mis-spent? How much money should a school district spend on science instruction if achievement scores are lagging? Should a school district emphasize achievement in science to the same degree as achievement in reading?

These and other questions are difficult to answer, and as a result, the accountability movement has been resisted by many science teachers. On the other hand, there is no evidence that the accountability movement is diminishing. Science teachers need to become more involved in considering these questions so as to better direct evolution of science curricula and of science teaching. Furthermore, science teachers need to become involved in searches for positive ways to improve student achievement in the sciences. Finally, science teachers must work with their colleagues in other academic areas so as to improve the educational environment and total curriculum of schools. Failure to make needed improvements in the schooling of contemporary students will be accompanied by societal demands for stronger accountability measures.

Changes in Science Students

Another cause for concern among science teachers is the change in the nature of today's students in both elementary and secondary schools. During interviews used to gather data for this working paper, many experienced teachers reported that as many responsive and bright students were found in schools today as in the past. However, these teachers reported that there have been subtle changes in their classes as a whole. They reported many students appeared passive and sought quick solutions to problems. They perceived growing restlessness and disinterest among students. Questions about the lack of motivation of many of today's students have become a real concern. There have been many attempts to explain how and why students are different today. Television has been blamed for some of the changes in students. Working mothers, one-parent families, and the isolation of youth from the mainstream of adult life also have been often cited as factors that have contributed to the changing attitudes and behaviors of school-age youth. Poor nutrition, part-time jobs, food additives, drugs, an emerging youth culture, and a host of other reasons have been given to account for the many changes in students today. Though there has been disagreement over why students are different from those of 15-20 years ago, there seems to be much agreement that students have changed and, as a result, science teachers have been confronted with new problems.

Unionization

The unionization of teachers is a relatively new element in science education. Unionization is neither purely a cause for hope nor a cause for concern. Unionization, as well as national, state, and local teacher organizations and associations, has influenced the teaching of science and will continue to do so. Employment and placement of new teachers, class size, inservice programs, staffing patterns and procedures, and salaries have been influenced by the actions of unions and teacher organizations. The influence of the unions and organizations must be considered in efforts to improve instruction and curriculum in science.

RECOMMENDATIONS FOR THE COMING YEARS

Faced with increased public disappointment and disaffection, declining enrollments, a new and different generation of students, resistance from taxpayers, reduced appropriations, and the rapid increase in amount of available scientific knowledge, science teachers at all levels of schooling have begun to look for new directions in curriculum and instruction. The general goals outlined in this report are supported by most science teachers. However, there is disagreement over how these goals can be achieved. Some teachers believe that the curricula developed in the 1960s through NSF support are too academic and esoteric to meet the needs of today's youth and society. These teachers propose interdisciplinary and issue-oriented courses so that there will be more emphasis on the current concerns and problems that emphasize the relationships between science, technology, and life. In short, some science educators charge that much of the traditional content of the science courses of the 1960s is too academic and irrelevant. Others argue that relevance is "the garden path to ruin."

Diversity of thought and values among science teachers should be viewed as a strength rather than as a weakness. Further dialogue on the direction and methods of science teaching must be encouraged, supported, and sustained as the wide spectrum of student and societal needs demand flexible and diversified approaches to the teaching and learning of science. Due to the growing recognition that the science curriculum has to be more adaptable to meet changing needs and current demands, many of the recommendations of this report will focus on curriculum development.

Curriculum Development

Curriculum and curriculum development have been defined and viewed in various ways. These definitions and views represent a variety of approaches to schooling and education.

Some educators equate the curriculum with a textbook, course of study, or collection of materials and/or activities. Others, having a broader definition of curriculum, view it as the sum of a student's experience both in and out of school. As a result, both intended and unintended experiences and learning are a part of the curriculum. Despite the recognition that many factors affect the educational experiences of students in and out of school, many educators find it useful to define curriculum in a more restricted manner. The National Institute of Education (NIE) defined curriculum as "the intended outcomes of instruction (i.e., all knowledge, abilities, skills, attitudes, values, behaviors and other attributes intended for acquisition by learners)".³⁰ Instructional programs are defined by NIE as "embodiments of the curriculum in the forms of plans (e.g., designs, goal statements, objectives, guides, descriptions, explanations, instructions, and materials (e.g., textbooks, film, filmstrips, slides, maps, workshops, ditto sheets, etc.) for use in instruction."³¹ In this document, the concept of curriculum and instructional programs as adopted by NIE will be used.

In an earlier section of this working paper, the need for school settings that were adaptable and diversified was recognized. All students in science should not be expected to pursue or achieve the same learning outcomes. Furthermore, students seeking similar outcomes should not be expected to pursue them in the same manner and rate. There may be certain concepts or skills that are basic in the education of scientifically literate citizens. Every high school graduate, for example, should be able to interpret data and know that matter is composed of particles. However, it seems unnecessary that every high school graduate will have studied molecular biology and chemical bonds in equal depth. The scientists and educators working under the auspices of the Biological Sciences Curriculum Study in the 1960s recognized this principle when they designed three different approaches to the study of biology. Other curriculum developers have also recognized the need for flexible and varied instructional programs that provide options for policy-makers, teachers, and students.

How far should this flexibility extend? What knowledge is relevant and necessary and what has become obsolete and useless? How should a science teacher answer the educator who asked "In what sense do adolescents need to know atomic theory, the gas laws, wave motion, characteristics of the electromagnetic spectrum, the Krebs cycle, or the hundreds of other topics which make up the traditional biology/chemistry core of our science education programs?" If the principles, concepts, and processes in these and similar topics are not studied and understood by a majority of students, goals of scientific literacy will not be optionally fulfilled. There must be continued emphasis on the processes, concepts, principles, and generalizations of science as they are enduring, valuable, and necessary in an era of rapidly expanding knowledge. However, it seems unwise to concentrate solely on discipline-oriented topics and courses. Science cannot be divorced from the critical realities of contemporary life and society. Neither can science continue to be seen as value-free. Science must be studied in the context of the times and society. Thus, science has many dimensions. Knowledge is only one dimension. There are also philosophical, moral, ethical, and practical dimensions of science. These dimensions of science must also be a part of instructional programs. When the many different dimensions of science are combined symbiotically in the curriculum, a larger number of students will gain greater benefits from science instruction.

Many of the contemporary instructional programs in science are useful in meeting the aims and needs defined in this paper. However, it seems highly probable that some of the existing programs are not suitable for many students and are inadequate to meet contemporary aims and needs. As a result, curriculum development in science must be a continuous process to respond to new conditions and needs.

Elementary Curricula (Grades K-6)

During one stage in the drafting of this paper, 54 elementary school science instructional programs were identified. At least 20

of these programs were considered to have been developed in accordance with contemporary theories on how children learn. Fifteen of the programs were provided in short units which the teacher could select and then use to modify instruction for individuals and groups. Laboratory kits or other materials for direct experimentation were provided by 26 of the programs.

An influx of new instructional programs probably is not needed as a large number of contemporary programs seem adequate and appropriate for meeting the needs of students in grades K-6 at the present time. Dissemination and implementation do seem to be more important problems currently. Many exemplary instructional programs are not being used widely. Others are being used less and less. In particular, programs emphasizing inquiry and active involvement with materials and operations apparently are being utilized by fewer school districts than a few years ago. Why are present programs used less than expected? Certain programs require management skills that pose problems for some teachers. Other programs present budgetary problems because of needed equipment and materials. However, the decline in use is probably more directly related to changing priorities in the schools and communities, and there is need to examine these priorities with care. If new elementary science programs are developed, it is important that they be designed in a manner consistent with the important priorities.

There is a need for the development of more suitable support materials such as books, film loops, audiotapes, games, and simulations. To be valuable, new supplementary materials must accommodate the vocabulary and the level of cognitive development of the intended users. Many existing supplementary materials fail to do this. Materials which combine science and reading or science and mathematics would also be useful inasmuch as there is some evidence that such combinations are effective.³²⁻⁴⁵

The National Science Teachers Association supports the principle that instruction in science should be provided in an appropriate form for students of all ages. It also strongly supports the study of science for young children. The development of scientific literacy must begin at an early age. The knowledge children acquire concerning the natural world adds a most important dimension to their lives. Furthermore, there is evidence that experiences in science are very important in developing the child's approach to life as an active, thinking being rather than as a passive and sluggish receiver. Evidence is emerging that further promotes the value of teaching science to children. The comprehension of science requires certain cognitive competencies. The same is true in reading. Formal operational thought is necessary for mature reading. Can activities in science facilitate the development of the mental competencies needed for reading? There is emerging evidence that indicates this question may be answered affirmatively. Also, science courses involving active experience with materials and measurements have been shown to raise I.Q. and improve mathematical abilities of children as well as to promote curiosity and creativity. A number of studies indicated that disadvantaged children gain many benefits from the study of science

during an early age.^{46,47} In comparison with other basic areas of study, science has been shown to improve the problem-solving skills and the attitudes of such children more, and to increase their chances of success in later years of school.

Despite the value of early and continuous experiences in science, the presence of exemplary instructional programs, and the obvious interest children have for science, the emphasis on science in elementary schools continues to decrease. Budgetary reductions for science and changing priorities must be challenged. Deficiencies in the preparation of elementary teachers (to be considered later in this document) and problems involved in changing the traditional curriculum have also contributed to the weakened position of science in elementary curricula. If purposeful science experiences are to be available to all youth, progress in all these areas of elementary science education is necessary.

Curricula for Junior High School (Grades 7-9)

The science curriculum of junior high schools should reflect the uniqueness of students in grades seven through nine. For most students, this is a period of transition and adjustment. The physical changes of puberty create new images and feelings as well as anxieties. Students of this age are developing new relationships with their peers, parents, and teachers. Sometimes these relationships are shaped in a harmonious manner. In other cases there is rebellion. Peer pressure and influence play an important role during these years as youth are involved in exploring the various aspects of emerging adolescence.

During this period of life, many students move from concrete to abstract or formal operational thinking. Inasmuch as the movement from one stage to another is uneven among individuals, additional differences among junior high students occur, making it more difficult for one approach to the teaching and learning of science to be appropriate.

Students in junior high schools also possess varied backgrounds in science. Certain students have attended elementary schools or had individual elementary teachers who emphasized science. Others were in elementary classrooms where the study of science was ignored. The mobility of the nation's citizens also results in a student population that has come from a variety of elementary schools representing different sections of the country. The result is increased heterogeneity in terms of background in science.

The uniqueness of junior high youth and the diversity of their needs, interests, and backgrounds are challenges to curriculum specialists and teachers. The junior high science curriculum should not be a scaled-down version of the traditional senior high programs. Neither should the junior high science curriculum be the textbook-oriented, read-about science program that exists in many localities and schools. Student-centered courses which are flexible and offer

opportunities for exploration, discovery, and student choice must be available. The natural and social context of the emerging adolescent must be used as reference points in the selection of content and activities. Materials and activities for small group and individual work must be developed. Instructional programs must exist which allow for the differences in mental development among youth of this age.

Finally, if junior high schools are to provide opportunities for exploratory studies (one of their important goals) and move students toward scientific literacy, a complete curriculum in science must be available. While reading skills are important and should be given special attention in junior high schools, the tendency to reduce offerings and requirements in science should be resisted, for it is contrary to the philosophy and goals of junior high school education.

Curricula for Senior High School (Grades 10-12)

Because of the diversity of needs, interests, and abilities among senior high students, a wide range of instructional programs must be available in grades 10-12.

(A similar recommendation was made for junior high schools in the preceding section.) First-hand experiences with the phenomena and material of science are a necessary component of a student's study of science at this level as well. Inasmuch as the cognitive development of many students has not reached the stage where abstractions can be understood, direct and concrete experiences in science are needed to enhance the learning process. Furthermore, laboratory activities and investigations provide common experiences that provide a basis for classroom discussion and reflection. There is also evidence that active involvement is important in maximizing a student's learning. Laboratory investigations provide opportunities for such involvement. Open-ended, inquiry-oriented laboratories also provide needed investigation. Laboratory experiences also provide opportunities for the development of attitudes associated with scientific inquiry. There is evidence that students who have had proper laboratories are better motivated than their schoolmates whose science courses have not included a laboratory, and that laboratory experiences improve student attitudes toward their work.⁴⁸ Finally, investigations in science provide students with opportunities to be creative and to examine real problems. It is encouraging to note that some high school students through their work in truly investigative laboratory courses have made contributions to the science profession through publications in journals of science and useful participation in research projects.

The laboratory experiences required to provide these opportunities need to be investigative. Too often, laboratory experiences are used only to verify or confirm what has already been discussed in class or read in the textbook. As a result, the students know what results to

expect and merely follow the directions to obtain the prescribed results. Such activities are not investigative and, as a result, are not useful in promoting desired skills of inquiry.

The senior high school science curriculum could be enhanced by the development of new courses and the addition of new areas of studies. Traditionally, there has been a lack of emphasis and courses in scientific fields of general interest such as astronomy, oceanography, geology, and meteorology. Despite the increased emphasis in environmental science, there are few laboratory courses or units in this field. Laboratory-oriented instructional programs need to be developed in all of these areas.

Also, as research and emerging knowledge open up new areas of inquiry, existing curricula must be revised. As an example, in the biological sciences, areas such as biogeography, bioengineering, sociobiology, psychobiology, and human ecology are becoming more important. These and other emerging areas of scientific endeavor deserve a place in the curriculum.

Course experiences relating science to technology, human values, and the social context should be developed so that students would have a better view of the significant role and influence of science in their individual and community lives. These experiences would help answer questions such as "What differences do scientific discoveries make?", "What is the relationship between science and technology?", "What has been the effect of science and technology?", "What has been the effect of science in society?", "What does scientific knowledge mean to the individual?", "What would be the effect of imposing limitations in certain areas of scientific endeavor?", "What desirable futures can science and technology help create?" and "What are the responsibilities of citizens in a technological age?" Students would become aware of various science-related issues in society. The development of these courses and emphases would mean the study of science would be extended beyond the boundaries of one discipline. The theoretical and conceptual structure of science would still provide the foundation and substance of science curricula, but there would be an increased emphasis on placing the study of science into the perspective of the past, present, and future society.

There are also other areas of need where curriculum development activities would be useful. Efforts to develop units that combine various science disciplines need to be continued. A series of "catch up" or tutorial units suited for individual study or for small groups needs to be developed so that students whose science backgrounds are less rich than those of their classmates will have opportunities to eliminate certain deficiencies. There is also a need for instructional programs that are constructed on Piagetian principles. The traditional assumption that most high school students have achieved maturity in their mental development must be discarded in view of the evidence that a majority of adolescents and adults in this nation are not at the formal operational level of cognitive development. Thus, there is a present need for high school science courses that make

provision for the large number of students who are concrete operational in cognitive development and therefore unable to understand and reason with many important but abstract scientific concepts, relationships, and theories. Finally, there is a need for instructional materials for students whose native language is not standard English. These materials should not be in language other than English or utilize dialects. They should be written so that difficult syntactic concepts are clearly and slowly introduced. Also, difficult words should be defined. The presence of a large number of inherently interesting activities which have the potential to involve students and provide them with common experiences which they later can discuss would not only help these students learn science but would also promote their language development.

The development of various alternatives to the present patterns of science curriculum should provide access to more areas of study, make it possible to meet the needs of more students, and create an overall curriculum that reflects the current nature of science and society. This must and can be done in a manner that will not result in simplistic or second-rate science courses that misrepresent the theoretical and conceptual dimensions of the disciplines of science. Furthermore, the high school science curriculum must receive constant scrutiny and revision so that the content is current and appropriate and the methodology provides optimum conditions for learning.

Science Curriculum for Two-Year Community Colleges

More, perhaps, than any other educational institution, the community college has a multiplicity and diversity of goals. These colleges are a source of general post-secondary education for many students some of whom will eventually transfer to four-year institutions. Vocational training, supplementary accreditation courses, and enrichment courses for various occupational workers are provided. Courses that provide skills for use in leisure time as well as day-to-day living are provided.

In accordance with this multiplicity of goals, the community college should offer a number of different science programs. For citizens seeking further knowledge and understanding in various areas of science, there should be independent, multi-media units which do not necessarily involve laboratory work. These courses would be developed so they could be used in local classrooms, club houses, or meeting halls. Possible subjects for such units include nutrition and preventive medicine, recent advance in medicine, recent inventions and their scientific bases, the solar system in the universe, the ecology of the region, urban pollution control, new sources of energy and their accompanying problems, methods of energy conservation, and recent advances in agriculture. Subjects such as these are undoubtedly being taught today. Thus, as a vital first step, information describing existing courses must be gathered from various junior colleges, community colleges, hospitals, museums, planetariums, public health organizations, and other institutions offering adult education courses. Locally developed materials of

general interest would be identified and described so that other institutions and individuals would have access to them. NSTA supports and encourages continuing education in science and supports the survey and summary described.

Courses aimed at general literacy in science should be available for students working toward a two-year degree or certificate. A number of courses recommended in this document for the high school curriculum also would be appropriate if designed at the appropriate level. It is important that these courses emphasize laboratory investigations. Furthermore, the courses should utilize various media that will allow the poor reader or individuals unskilled in standard English greater access to course content.

In planning a curriculum for the two-year student, as well as for the student intending to transfer to a four-year institution, it is important that the instructional program offered be articulated with that of both local high schools and state universities and colleges. Communication between community college science teachers and high school science teachers has been very inadequate. The relationships between science faculties of community colleges and four-year institutions also need to be improved. NSTA should promote a continuing mutual relationship among those involved in the teaching of science at all levels. A variety of benefits would result, including improved articulation between the science programs in public schools, community colleges, and four-year institutions.

Science Curriculum for the Four-Year College or University

Among the current efforts to revise college science courses, NSTA views as important and welcomes the current interest in designing courses in accordance with theories of cognitive development. There must be continuous efforts to inform college teachers of recent developments concerned with the psychology of learning and strategies of instruction. Support and assistance must be provided these teachers so that contemporary knowledge regarding teaching and learning can be reflected in the learning experiences they provide students. It is important that these learning experiences include investigative laboratory activities. Because of the centrality of the laboratory to the study of science at all levels of schooling, NSTA opposes the trend to eliminate laboratory experiences from introductory college science courses.

Finally, NSTA believes there is a need for improved communication between faculties of science and science education departments. In some places there are encouraging signs of increased cooperation and collaboration between these faculties; if such relationships continue, more appropriate learning experiences for students in science at all levels of schooling should result.

Science Courses in Preservice Teacher Education

In 1969 the American Association for the Advancement of Science (AAAS) formulated and published guidelines for the preservice science education of elementary teachers.⁴⁹ During the same year, the NSTA publication, Designs for Progress in Science Education, made similar recommendations for the preservice education of both secondary and elementary teachers. NSTA continues to endorse these guidelines but, in addition, other needs exist. Many institutions have not followed these guidelines with any consistency. Others have not followed them at all. It is time for more positive action and response to these guidelines.

Many state education agencies have responded positively to the recommendation that prospective elementary teachers receive both a science course with a laboratory and a science methods course. However, in recent years, many states have removed this requirement. As a result, it is possible for elementary teachers in some states to be certified without any credits in science. Inasmuch as most science in elementary grades is taught by generalists rather than by specialists, it is imperative that all individuals preparing to be elementary teachers have some background in the biological, physical, and earth sciences. Therefore, students in elementary education should neither graduate nor be certified without completing at least one laboratory course in science. Preferably, there should be a course available emphasizing several of the sciences in a unified manner. Furthermore, this course should be taught in a manner that would result in students developing a positive attitude toward the study of science.

Elementary education majors should also enroll in science methods courses that emphasize the type of activity-oriented experiences that are being recommended for the children they will eventually teach. The significance of laboratory experiences at all levels of schooling has been explained earlier in this document and will not be reviewed here. However, the importance and significance of these experiences must be made known to university policy-makers so that funds needed to purchase activity-based science instructional programs for use in science methods classes may be made available. Students, science education faculty, and professors teaching general curriculum courses need the experience with science materials currently available to the schools.

Despite improvements, the subject matter competence provided by a typical undergraduate sequence of science courses required for certification is usually inadequate. A major problem noted by Hurd is that "The college or university major for science teachers is not typically based on a content analysis of school science curriculum, or in other words, what the teacher is expected to teach."⁵⁰ Also, much of the subject matter competence needed by high school science teachers to teach the courses recommended in an earlier section of this document is lacking. To remedy this deficiency, new college courses designed to foster needed skills must be developed and used in place of some traditional courses.

Generally, neither elementary nor secondary school science teachers have had the benefit of studying science in collegiate science courses where the teaching emphasized inquiry and the development of concepts. Model interdisciplinary courses have been even rarer. Elimination of these shortcomings would do much to enhance the undergraduate preparation of teachers of science in the elementary and secondary schools. Programs would be even more worthwhile if prospective high school science teachers were to be involved in original research.

Evaluation and Assessment

There is a continued need for the development and refinement of appropriate evaluation instruments. Additional data for curriculum development and the improvement of instruction are constantly needed. In particular, data concerning student progress and the influences of different curricula and instructional strategies are important. There has been a proliferation of instruments that produce data of this type, but new problems have resulted. The many different instruments produce results which are difficult to compare; often they have not been properly validated and made reliable. One authority in the field, in citing the disparate results of attitude studies, concluded:

In general, this writer would like to see less proliferation of instruments and more use of the same measures in a variety of studies.... One reason research in education, and specifically in science education, so often fails to give us the kind of guidance we need to make decisions is the lack of replication studies. We do not know enough about the specific limitations of variables or for what kinds of students certain treatments are especially helpful or wasteful.⁵¹

Another problem with many instruments available for measuring the effectiveness of instructional strategies and student growth is that they generally are concerned with only a few factors. Too often, student progress is measured on the basis of the acquisition of facts while other types of student learning in science are ignored. Instructional programs must be evaluated for more than their success in providing students with factual information.

The development of attitudes has been seen as an important outcome of instruction in science. However, data concerning progress in this area are inconclusive. There have been studies concerned with the development of attitudes but "there is little indication that any constellation of attitudes toward science can be related to effective instruction in science."⁵² Thus, it is obvious more work needs to be done in this important area of research.

Instruments that can measure the science achievement of young or disadvantaged children are needed also. These instruments need to be

developed in accordance with the knowledge that these students can demonstrate understanding in concrete situations long before they can verbalize the concepts involved.⁵³

One reason for the relative inadequacy of many of the diagnostic instruments available for measuring the outcomes of instruction in science is that they have been developed by individuals who have not been directly involved in the sciences or in science education. Despite their expertise, psychologists and others have been unable, for the most part, to construct assessment instruments that yield a satisfactory range of information. NSTA recommends that college teachers in the sciences and science education be trained in the techniques of testing and evaluation so that they can work more productively and effectively in the field as well as train elementary and secondary school science teachers in the same techniques. It will then be possible to have a more coordinated effort to construct, test, and validate a few multivariable instructional programs and strategies through data obtained from measures of student progress. The future success of curriculum development and the development of effective patterns of teaching depends in large measure on the collection of useful data. Thus, evaluation and assessment must receive higher priority in the science education community.

Laboratory Equipment and Supplies

The need for appropriate laboratory experiences has been repeatedly recognized in this document. However, there is evidence that many schools are not equipped to provide such experiences. According to a 1971 ERIC survey,⁵⁴ only about one-third of the elementary schools had special science facilities.* Thus, most of the science instruction that occurs in elementary schools is in regular classrooms. Teachers in such schools generally report that they use laboratory activities infrequently. Based on a scale in which a rating of four indicated frequent use and zero, no use; the national average for individual laboratory activities was 0.88 and 1.41 for group laboratory activities. This survey revealed that 86.2 percent of the classes in the survey sample of high schools were taught in laboratory classrooms and most teachers seemed to use group or individual laboratory work at least some of the time. In 1971, even though most high schools had annual budgets for laboratory equipment and supplies, there was still a substantial minority that did not. No information was given concerning the adequacy of the high school budgets, but most elementary school budgets were judged adequate by teachers. However, this is not surprising as apparently they were not using laboratory activities with any regularity. Today, there is reason to believe the science budgets of many schools have been reduced or eliminated. This trend is

*There is a possibility this number may be smaller as a number of schools that did not respond were thought to be schools in economically deprived areas where the physical provision for elementary school science may even be less.

unfortunate and must be reversed because of the importance of laboratory experiences at every level of schooling.

Alternate methods of supplying and equipping science laboratories must be considered also. A number of schools and school districts have coordinated their science programs so that expensive equipment which is important but used infrequently can be shared. Many schools have established science material centers that collect and distribute perishable laboratory materials at low cost. They also purchase and loan specialized equipment. Some centers have demonstration laboratories that teachers and able research-oriented students utilize. Others provide science teachers with facilities, equipment, and materials to construct needed teaching aids. Also, certain school districts are beginning to utilize community resources available such as museums, universities, and a wide range of industrial settings. NSTA encourages the development of such centers or cooperative ventures where they do not yet exist.

NSTA also encourages the development and sharing of inexpensive audiovisual resources such as audio-cassettes, video discs, and similar learning aids by school districts. Appropriate science materials available in cassettes or discs in a school library or media center can be a valuable and inexpensive supplement to laboratory courses. More attention also needs to be given to the use of video equipment. Videotapes can be useful adjuncts to the science curriculum. Schools with poorly equipped laboratories could benefit particularly from the availability of videotapes on a variety of topics in science. However, care must be exercised so that the centrality of laboratory activities in science is not destroyed by misuse and reliance on media presentations.

Despite the usefulness and continuous need for media to teach science, an over reliance on such vehicles for learning may leave the student passive and deprived of necessary involvement. Thus, ways must be found to involve students actively when media presentations are used. Suitable handbooks or other teaching resources must be developed to accompany media used in teaching science so that students will be engaged in an active study of science.

Improvement of Teaching

Inservice Education

As stated earlier in this working paper, science teachers have varied opportunities for continuing education, inservice experiences, and self-improvement activities. However, these activities are not organized into overall meaningful programs. Opportunities must be expanded and made available on a continuing basis so that science teachers will be informed as new knowledge in the sciences becomes available, research on methods of science teaching produce new techniques, and new curriculum materials are developed.

Despite widespread agreement about the need for continuous inservice activities, there is much discontent over the availability and nature of inservice education. Many teachers still report that limited opportunities for inservice education exist in their areas. Other teachers indicate that heavy teaching loads prevent them from participating in inservice activities even when they are available. Inservice activities often are scheduled after the school day when teachers are both mentally and physically tired. Many of the after-school and weekend inservice programs are attended by the same, few, busy science teachers who are constantly seeking to improve their knowledge and skills. However, it is not reasonable to expect these and other teachers to participate continuously in inservice activities at these times. Teachers must be allowed more time for inservice education during the school day. Also, more extrinsic incentive must be provided for teachers to participate in summer inservice activities.

The nature of many inservice meetings has also been a troubling factor. Too often, inservice programs feature meetings that have not been preceded by any teacher input or planning and will not be followed up in any way. Such meetings normally result in a minimum of new insight and progress. Effective inservice programs must be initiated locally and adapted to specific needs. Inservice education cannot be imposed by either internal or external groups and cannot consist of one session at some center or campus. Growth and development require continuous articulated opportunities that have been planned and organized around the needs of the participants. Much support for this premise exists in the research and literature of the profession. Furthermore, needs assessment instruments and methods of collaboration have been developed that facilitate the planning of inservice activities around the needs of teachers.

As a result of the development of many new instructional programs in science during the past two decades, much inservice activity has been needed for successful implementation and adaptation to local needs. It now appears that the successful introduction of a new instructional program or technique demands more than one year of continuing inservice activity. The typical introductory workshop must be followed by discussion, classroom visitations, meetings among teachers using the new curriculum or technique, and possibly more summer workshops. Initial enthusiasm for a program or a new strategy likely is to be followed by disillusionment if the teacher is not helped to meet the various problems that arise during the implementation period which may extend into a period of two or three years.

Experiences gained through inservice activities can be further maximized by appropriate scheduling and staffing patterns. It is not uncommon for teachers who have spent considerable time in NSF-sponsored inservice programs to be assigned positions where they cannot use their expertise. Other teachers have spent several summers of academic study in a special area of interest and then find themselves reassigned to teach in an area where their preparation and interests are much more shallow. If inservice activities

are to be useful in improving the instruction and curriculum in science, schedules and staffing patterns must be planned together by teachers and administrators.

Science coordinators and consultants in local school districts are important in planning, initiating, conducting, and following up inservice programs. Their continuous presence and interaction in the schools allow them to know teachers and programs. They are familiar with the goals and objectives of their school districts. Science supervisors are knowledgeable in the sciences as well as in the literature and research in education. Many science consultants have close contact with external agencies and state, regional, and national associations in science education. Science consultants have the needed skills and knowledge to foster professional growth and inservice education by performing several functions, such as identify teacher needs; describe needs of science teachers to administrators, school boards, science education centers, and various external agencies; design and implement appropriate inservice programs; transmit information about new instructional programs, current research results in science education, and promising teaching strategies; assist teachers in arranging needed leaves and school visitation opportunities; assist teachers in efforts to improve instruction; assist teachers in assessing existing science programs; provide leadership and assistance in the examination, implementation, and evaluation of new instructional programs, help in establishing local material and demonstration centers where teachers can obtain needed equipment and material and learn about new laboratory procedures. Local science consultants can arrange needed forums where science teachers from high schools, community colleges, and colleges can exchange information and views as they work together to articulate and develop the science programs of their respective departments. By performing these functions and others as defined by the National Science Supervisors Association (NSSA) in a recent publication,⁵⁵ science supervisors play an important role in the inservice education of science teachers.

During the 1960s the number of positions for science consultants and coordinators increased. This is no longer occurring and in some school districts the positions are being discontinued. This trend must be reversed as science teachers recognize the importance of local science consultants and welcome their support. In 1965, a study asked teachers to rank 13 items considered as barriers to effective science teaching. "Lack of adequate consultant services" was ranked first.⁵⁶ Today, it is essential that these services are provided to science teachers.

State science supervisors play an important role in inservice education. They provide inservice opportunities for both consultants and teachers. They possess skills and knowledge useful in assisting with many instructional problems. They provide valuable input into decisions regarding teacher certification and the design of undergraduate and graduate teacher education programs. State science supervisors collect and provide needed data to state and national

legislative bodies. They also develop and administer programs funded by federal sources. These and other functions make the state science supervisors indispensable in the process of improving science instruction and curriculum in this nation. States that are discontinuing the positions of science supervisors are weakening science education programs in their schools.

Funds must be made available to employ science consultants in states and school districts where they do not exist. Because of the temporary absence of science consultants in various school districts, science educators and associations should contribute to the publications and conferences of school administrators so that they can be informed about the needs of science education. Also, as a beginning or a stop-gap measure, large schools should utilize a science teacher in the building as the science coordinator. This person should be given a reduced teaching load.

Science educators at local colleges and universities also are valuable individuals in providing inservice education. Most science educators are experienced science teachers and have continued professional experiences in elementary and/or secondary schools. They possess knowledge in the sciences as well as in science education. The current efforts to minimize and even remove responsibility for the professional development of teachers from colleges and universities must be resisted. Instead, efforts must be increased to develop a partnership that will allow science educators in institutions of higher education to respond to the many needs of the science teachers of the nation.

Inservice education should be a continuous process. Science teachers should assume personal responsibility for their professional growth and development. Federal, state, and local authorities must recognize the importance of inservice education and provide support for needed programs. Many corporations have resources that need to be made available for inservice opportunities for teachers. Colleges and universities must design graduate programs that will meet the needs of science teachers. The consensus, among science educators, is that quality inservice education is the most important factor in the health of science teaching as a whole and the factor most in need of continuous attention.

Preservice Education

Beyond strengthening inservice education, work is needed to improve science teaching through preservice education. One study,⁵⁷ Research in Science Education Survey (ROSES), conducted in 1965-67, questioned school administrators, cooperating teachers, science teachers, and science teacher candidates and found that many prospective teachers felt their education courses were irrelevant to their future teaching. Many cooperating science teachers considered the colleges of education to be describing what ought to be done in an ideal state of affairs. Many school administrators complained

that they had to train recent graduates of science teacher programs to teach science in the real world of the school. Both schools and teacher candidates complained that many candidates were supervised inadequately during their field work and many prospective elementary school teachers had no opportunity to observe or to participate in elementary school science classes. Other more recent surveys agree with the ROSES findings.⁵⁸

Various explanations of these deficiencies have been offered, including the view that prospective teachers are not exposed to a coherent philosophy of teaching and learning, or that they fail to acquire a proper attitude toward change. The cry from the field, however, is for practicality, not philosophy, and although rational practice must be based upon sound theory, sound theory and positive attitudes may best be developed in the context of practical experiences in schools. This view is supported by research which has shown that the cooperating teacher and school have a profound impact on student teachers. Unfortunately, this influence is not always good. Research confirms that student teachers often discard humanistic approaches taught in some colleges, adopting a more custodial approach stressing order and control.⁵⁹ It also is agreed generally that there are too few science teachers who provide adequate models for the teaching of the new science curricula.

Findings of research on teacher education can provide guidelines for programs. It has been shown, for example, that guided observation and practice with students is more effective than formal lectures on instructional theory and human development.

The supervising teacher in the school is a key person in teacher education; preservice and inservice education merge in the schools. Efforts should be made to create a cadre of enlightened cooperating teachers, capable of participating as full staff members in the teacher education process. Some colleges, in a few locations, have initiated such programs.⁶⁰ These programs share a number of promising features: they give the "model" teacher formal recognition as an adjunct member of the college staff and great responsibility for directing the student teacher education; they give the students extensive and diverse teaching experiences, culminating in full responsibility for one or more science courses; they involve students, model teachers, administrators, and college personnel in seminars at the school, where real problems are aired. Programs such as these are needed. However, they need to be suited to the different circumstances of different communities.

Competency-Based Teacher Education

Competency-based teacher education (CBTE) has grown in importance during the past few years. Estimates indicate half of all American teacher education institutions are developing CBTE programs while half of the states have adopted or are moving to adopt certification and accreditation standards that are competency-based. This movement is

a reaction to traditional standards that have been defined in simple terms of completed credit-hours in specified courses and areas. By demanding performance, rather than "credits" on paper, educators and state authorities are demanding "teacher training in which the prospective or inservice teacher acquires, to a prespecified degree, performance tendencies and capabilities that promote student achievement of educational objectives."⁶¹

Competency-based education has problems similar to other "accountability" procedures. Its definition presupposes measurable "degrees" of "behaviors" and detailed specifications which are difficult to identify. This problem has been recognized by many science educators. The National Dissemination Center for Performance-Based Education concluded "we have no firm evidence that one set of teaching competencies is more productive of learning in children than another set; that one level of competencies is more productive of learning in children than another set; that one level of competency definition is better than another level; that one approach to program organization is better than other in bringing about desired competencies."⁶² The "success" of a particular lesson or series of lessons may depend on variables such as the attitudes and previous learnings of the student, the availability of proper instructional resources, events in the school and community, the social structure of the class, and finally the quality of instruction.

Classrooms are dynamic. To what cues should a teacher respond in making decisions and in using competencies? How are competencies to be integrated within a dynamic classroom? Clearly, the whole matter of competency-based requirements demands further study. There has not been enough research on the relationships between instructional strategies and student performance to make definite pronouncements at this time.

Community Involvement

As citizen involvement in schools increases, guidelines and models must be developed that clarify and delineate the roles and responsibilities of students, educators, and citizens. Furthermore, continuous efforts must be made to keep citizens informed and involved as innovative practices and instructional programs will not be accepted until understood by the community. Insufficient knowledge and a lack of understanding of program goals have resulted in the termination of educational innovations in many communities. Thus, plans for the improvement of the curriculum and instruction in science must necessarily involve participants from the community.

The relationships between schools and communities have not always been harmonious. Complaints that schools do not serve the community and that communities do not support the schools are common. There are also difficult questions to answer in regard to citizen involvement in schools. Who speaks for the community? What restrictions should be placed on citizen involvement? What extent should the skills, knowledge and decisions of educators be controlled and/or

influenced by the community and special interest groups? How can the wishes and expertise of citizens contribute to the improvement of science programs? Guidelines and models for delineating and clarifying the roles and responsibilities of citizens in setting goals, selecting curricula, assessing achievement, and determining conditions that influence school climate and learning are needed. Science teachers and science consultants must become involved and visible in the community to provide citizens opportunities for informal involvement in school science programs.

In many school districts, community involvement in the education of students has been increased and enhanced by moving programs into the community and by bringing volunteers into classrooms to assist with instruction. Public utilities, industry, museums, parks, medical facilities, and numerous other resources useful in teaching science are available in communities. Also, many individuals possess knowledge and expertise that can be utilized periodically in science classrooms to teach will benefit students as well as enhance school-community relationships as understanding develops through involvement. Finally, most communities have individuals who possess the necessary expertise to serve as valuable resources in curriculum development.

In recent years, the contributions of science-related industries have increased. Special projects and activities have been funded. Unneeded equipment has been donated for use in school laboratories. Certain corporations have provided much information about various careers. Mini-grants and awards such as the Westinghouse Fellowships have been available to support student research. In some communities science teachers have joined with representatives from industry to develop apprenticeship programs for disadvantaged youth. These contributions have been important, and to insure their continuance and expansion, more effort must be made to solidify the partnership between schools and industry.

Science teachers also can contribute directly to the community. Science teachers have the needed expertise to speak to clubs and organizations on a variety of science-related topics. Student-made exhibits concerned with topics such as conservation, pollution, or nutrition can be displayed in various locations in communities. Exhibits depicting the results of student research projects are also appropriate.

It is evident that schools alone cannot provide experiences and knowledge in science needed by contemporary youth. Thus, it is necessary that schools and community work together to provide appropriate educational experiences.

Research in Science Education

In discussing the improvement of instruction, the roles of the local classroom teacher and the local science consultant as coordinator of inservice education have been emphasized in this paper.

However, there are certain functions which local school districts are not involved in designing and conducting basic research concerned with teaching and learning. School districts also lack the resources to design and implement instructional programs in science that are based on reliable research findings in science and science education. These functions, so crucial for the improvement of instruction, usually are performed by university research centers or by independent centers staffed by doctoral graduates of university departments.

The need for further research in science education is great. Multivariable studies that avoid the false isolation of factors in teaching are needed. Studies concerned with classroom climate and interaction need to be conducted. There is a lack of studies on how to prepare science teachers in the use of new teaching strategies and techniques. When new instructional materials are tested in an experimental class, comparisons with matched classes using different materials are seldom made. Studies are needed that eventually may form the basis for matching teacher instructional styles with student learning styles and profiles. How can people be taught so that they will be stimulated to learn new concepts throughout their lives? How can people be taught to solve problems in rational, scientific and humane ways?

A recent study⁶³ supported by the National Association for Research in Science Teaching (NARST) found that a sample of its members gave high priority to research emphasizing "the acquisition and influence of teaching strategies or behaviors, applying theory and research to classroom practice, and relationships among teacher and student variables."⁶⁴

Long-term, cooperative research in the areas just outlined needs to be conducted. Early research efforts in science education suffered from poor methodology, but during the last decade there has been increasingly sophisticated and reliable experimentation. However, there has been too much fragmentation of effort into independent, short-term studies. Rowe, in calling for long-term research efforts, stated that "Far too many research studies encapsule too little pieces of time. For that reason we fail to understand the classroom evolutionary process. It is no wonder so many apparently promising techniques turn out to fall in the class of nonviable mutations."⁶⁵ Doctoral candidates should be encouraged to prepare dissertations on some aspect of an ongoing project or study. Science educators involved in research also must be more aware of the need for collaborative efforts on long-term research projects.

The results of research also need to be disseminated widely. Science teachers and consultants complain repeatedly that they are aware of little research evidence that can be applied directly in teaching. Teachers indicate they have difficulty in finding information that is both relevant and understandable. The lack of data concerned with the effectiveness of the vast number of educational products and programs makes it difficult for science teachers to make appropriate selections. The reviews of research provided by

ERIC, the annual summary of research in science education published by Science Education, and specific chapters within the yearbook of the Association for the Education of Teachers in Science (AETS) are all helpful. However, these general reviews contain brief descriptions of both successful and unsuccessful projects. Also, many classroom teachers do not have access to these reviews, and many who do have difficulty in extracting and translating the significant research into practice. Science and Children and The Science Teacher, NSTA's publications for elementary and secondary school science teachers, publish a regular feature titled "What Research Says to the Science Teacher." Additional efforts must be made to translate the data and conclusions of research in science education into a form useful and available to the science teachers of this nation.

Despite the need for research in science education, 60 percent of the members of the National Association for Research in Science Teaching (NARST) who responded in a mail survey indicated they had no budgeted research time.⁶⁶ This survey also indicated that research is not a major activity for members of NARST. The respondents had during the last five years "averaged about .35 research articles per year or an average of one published research article every three years."⁶⁷ If the needed data required for improvement of instruction and curriculum are to be available, the available time for research must be increased.

State and federal support for research in science education must increase so that researchers have budgeted time available to conduct both short-term and long-term research studies. Federal support especially is needed for comprehensive assessment of the science programs in the nation's schools. Surveys concerned with class sizes, textbooks used, characteristics and opinions of teachers, and related information have been valuable in the past and are still useful. However, there is a greater need for information on methods and curricula. There is a particular need for more data on the effectiveness of different instructional programs that exist today.

The expansion of research efforts in colleges and universities is complicated by staffing patterns in higher education. Stable or shrinking enrollments and budgets have resulted in few faculty vacancies in science education and the sciences. This, in combination with reduced federal support for graduate students and research, has resulted in fewer graduate students available to assist in research efforts. Many educators are concerned this is reducing the flow of new ideas and approaches into institutions of higher education.

The Encouragement of Women and Minority Students in the Sciences

NSTA has expressed intense concern about the relatively small number of women, blacks, and members of ethnic minorities in the sciences, engineering, and science education. There is widespread agreement that members of these groups must be encouraged to seek careers in such fields.

The reasons why relatively few white females choose careers in science probably are buried deep in our cultural heritage. Despite the relative freedom American women have enjoyed and the advances in independence which the last generation has seen, women are still less likely than men to engage in scientific work or engineering, though there are notable exceptions.

The reasons why relatively few Black, American Indians, Puerto Ricans, and Mexican Americans choose careers in science are more complex and somewhat different. Here, too, there is cultural stereotyping with its resulting inhibitions. There is also a history of educational neglect whose effects persist despite the efforts of the recent past. One result of the cultural deprivation minority groups have suffered is that fewer of their members are prepared to study science. Research has shown that certain mental powers must be stimulated early if they are to develop properly.⁶⁸ By the time students reach high school, poor black or Spanish-speaking inner-city students are usually far behind their peers found in wealthy suburban schools. Many of these students are accustomed to failure and cannot perform successfully in available science courses.

Science teachers cannot unilaterally change cultural attitudes, but they can work as individuals to display no sexual or ethnic bias in relating to students. In working to maintain graduation requirements in science where these exist and to reintroduce them where they have been eliminated, all students, including members of minority groups and women, are more likely to be given the chance to discover an interest in science. In strengthening and maintaining elementary school science courses, more young children will gain knowledge and skills in science and begin to realize that the study of science is a normal and essential part of everyone's life.

There are many members of minority groups who are making important contributions in science and science education. Efforts must be made to increase their numbers by improving early education in science and by encouraging able individuals to think of pursuing scientific careers. Many of the courses of action recommended in this working paper contribute to these ends. The strengthening of K-3 science studies, the creation of concept-building curricula for high schools, the development of curricula for students whose knowledge of standard English is weak, the creation of "catch-up" units for junior high school and high school students, the emphasis on intensive preservice clinical experiences in rural districts and in

inner-city schools, the call to increase the numbers of science supervisors so that they can promote local initiatives for inservice education, and suggestions for involving parents in school science programs should improve science education in schools teaching minority students and as a result, provide greater opportunity for student success in science courses. Equal access, even "recruitment," to scientific education should be promoted. Some teaching materials for elementary and high schools have been designed for this purpose. The National Academy of Engineering has a program for increasing minority participation in engineering. NSF has funds available for science teaching improvement and graduate traineeships in minority institutions, for the encouragement of women in science, and for preparing members of minority groups for scientific careers. Ultimately, students should be taught science in ways suited to their own mental development; all who show ability should be encouraged to pursue scientific careers.

Trends in Federal Support for Education and Their Implications for Science Education

In this working paper many steps have been suggested to improve science education in coming years. The development of new curricula; the creation of alternative curricula for junior high schools, middle schools, high schools, and community colleges; and the further support of existing curricula through laboratory resource centers have been recommended. The strengthening of preservice education programs, vigorous pursuit of inservice education programs through a restored network of local and state science consultants, and attention to long-term funding and research also have been advocated.

Many of these proposals involve local initiatives, or the stimulation of local initiatives; some of them involve national programs, or federally supported programs at research centers. Some of the proposals are recommendations to science educators, who may be expected to apply for grants from various agencies including the federal government. Some are recommendations to states or school districts which also may apply for federal funds. Some are recommendations to NSTA as an organization, which also relies on federal grants for some of its activities. What is the probability that science education will receive appropriations necessary to realize these goals? A partial answer to this question comes from an examination of current federal policy in education.

In February 1977, guidelines of the National Institute of Education (NIE) specified its future functions in curriculum development would focus on "(1) the conduct, synthesis, and dissemination of research on issues of curriculum, instruction, and learning, (2) efforts to strengthen, facilitate, or coordinate others' work in improving instructional programs."⁶⁹ The guidelines also stated that "In certain circumstances, NIE will take steps to ensure that (1) instructional products it has sponsored are made available to intended users and (2) potential users receive needed support in learning to use adopted products."⁷⁰ The "circumstances" or conditions required

the products be judged good and that supporting activities be required to realize the goal of equal educational opportunity or the meet the national need the product was developed to serve. The committee which accepted these priorities, added that:

One area of instructional program improvement has overriding importance in American education today and therefore should be given special emphasis. This area is the equalization of educational opportunity for students such as the bilingual, those affected by negative sex stereotyping, the handicapped, the disadvantaged, the geographically isolated, and those whose cultural heritage is often neglected in predominant courses of study.⁷¹

In its 1976 Databook, NIE stated that its research and development activities to 1985 probably would emphasize the application of technology to education, research on methods of ameliorating social problems, and the pursuit of new research paradigms or methods. It would also sponsor selected field-initiated studies intended to satisfy a researcher's curiosity on some point.⁷² However, somewhat different conclusions were reached in a report NIE commissioned in 1976 from the National Research Council and the National Academy of Science. This report found that federal agencies allot only 4 percent of their funds for research and development to basic research in education. It recommended an increase in federal spending for basic research, caution toward "premature attempts to provide quick solutions to educational problems," and more extensive use of "field-initiated and peer-reviewed systems of research finding." It further recommended that NIE "take immediate steps to implement a policy of strong support for fundamental research relevant to education" and "provide long-term support for work on important problems of education that affect broad sectors of society," and that NSF "establish a strong program of support for fundamental research related to science education."⁷³ In a 1977 report, NIE's National Council on Education Research spoke of a "sound balance among basic research, applied research, development, and dissemination," and stated that NIE "should concentrate on identifying, analyzing, and synthesizing knowledge resulting from education research projects funded by other sponsors."⁷⁴

The National Science Foundation supports a variety of programs in science education, through four of its divisions: Division of Science Education Resources Improvement, aimed at schools, colleges, and universities; the Division of Scientific Personnel Improvement, offering fellowships, support for teacher development, and programs for women, minorities, and the handicapped; the Division of Science Education Development and Research, directed at research and curriculum projects; and the Office of Science and Society, supporting science education for the general public and programs which study the relation between ethical values and scientific activities. The existence of these four divisions illustrates the scope of NSF programs, but no indication of its actual funding policy. The June, 1977, NSF Program Report, Models and Programs in Science Education, assessed the changing scene in education--fewer students, lower budgets, aging staff, fewer openings

for teachers--and concluded that the federal government should offer incentives for smaller, more diverse formal systems, and for larger, more diverse informal systems of education. It also concluded that the NSF's main efforts in development and research should be directed toward nontraditional activities of its "old audience"--colleges and universities--and of its new clients--two-year colleges and others.⁷⁵

It is apparent that the federal agencies most involved in the federal funding of education have no unified common policy and are still debating internal policy issues. These agencies do share certain priorities. They support programs for the disadvantaged, women, minorities, and the handicapped. They are beginning to recognize the need for long-term funding of basic research and dissemination of research results. Also, they are de-emphasizing full-scale curriculum development projects for traditional institutions. NSF seems willing to support needs assessment and development in evaluation. It also is supporting unorthodox educational efforts for the benefit of local communities. It is unfortunate that it has given low priority to projects for disseminating and implementing new curricula and for inservice training in general.

Despite cutbacks in funding and changing priorities, most of the recommended actions in this paper which require funding can find a possible source of support in one agency or another. Some of the recommendations for curriculum development would serve the needs of minority students. The recommendations for modular units are consistent with the decline in full-scale curriculum development. The proposals for improved methods of assessment should be supported by NSF. Much of the research recommended can be classed as basic research and seems supportable. Programs to educate classroom teachers, to improve schools in deprived areas, and to disseminate materials and ideas should attract support. Federal support for certain curriculum projects, certain inservice education programs, and science consultants may be harder to acquire.

Some of the agencies' priorities result, naturally, from budgetary constraints. For example, an NIE estimate reveals that the cost of installing a new instructional program is four times the cost of developing it. Economic realities and priorities must be recognized, but developing an instructional program without installing it is wasteful. Other agency priorities result from views on the problem of federal intervention. Members of the science community have expressed concern about increased federal intervention while recognizing its benefits. Federal agencies must be encouraged to develop appropriate priorities. At the same time, foundations, industries, and local authorities must be approached as sources of diversified funding for important programs and efforts in science education.

The science education community must take a more active role in providing input into federal and local agencies than it has in the past. When government agencies occasionally have sought the advice of science educators, the advice has sometimes been taken lightly. The science education community must organize the delivery of

information to government agencies, to organizations, and to school systems which fund, regulate, and administer programs. It must also monitor federal and state legislation which affects science education and alert its members to measures which require a response.

A system should be developed to gather information from science educators about needs, problems, and goals. NSTA should supply this information to government agencies and others on a regular and continuing basis. Elements of this system might include an annual conference of representative scientists and science educators established to articulate and prioritize current needs, problems, and goals. Concerned groups might also be encouraged to publish position papers. Committees capable of providing data and advice to state and federal bodies and agencies that influence various areas of science education should be formed. NSTA also should develop a system of gathering, monitoring, and disseminating information on proposed legislation affecting science education.

These proposed activities require cooperation from other organizations in science, science education, and education. A system for the regular exchange of views between such organizations should be developed.

In the years ahead, programs in science education should be responsive to the needs of all students and society. A high level of literacy in science must be achieved and maintained for all citizens. The educational process is complex, but it is not impossible to respond to the complexity in rational, scientific, and humane ways. There is reason to hope that public interest and support can grow and that increased parental and community involvement in the schools will stimulate support for well-prepared teachers and rich science curricula.

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APPENDIX I: OTHER CONTRIBUTORS TO POSITION PAPER

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APPENDIX III

THE TEACHER IS THE KEY

A Report on Three Studies by the National Science Foundation
of the
Status of Precollege Science, Mathematics,
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Abstract

The studies bring into focus current practices and conditions that affect science teaching. There is now more use of laboratory and hands-on instruction than there was before the development of new science curricula, funded by the National Science Foundation between 1955 and 1975. The NSF teacher institutes have also had an impact. However, at all grade levels the predominant method of teaching is still recitation with the teacher in control, using lectures and a textbook (usually only one) as the chief modes of instruction. Demonstrations are also used quite frequently, and in some cases other methods such as field trips, guest speakers, programmed instruction, and similar programs were observed. But for the most part such methods are used frequently and in many classrooms not at all.

In senior high schools, year-long biology, chemistry, and physics courses are still the norm. Most states require only one year of high school science; the majority of students study only tenth-grade biology. In the current widespread emphasis on accountability and "the basics," science is seldom considered basic.

Senior high school teachers for the most part feel well qualified to teach the subjects assigned to them. Junior high school teachers feel less well prepared, and a great many elementary teachers consider themselves ill-equipped to teach any science. There is clearly a need for better preservice and inservice training for teachers below the senior high school level.

Teachers also see a need for more on-the-job assistance, especially at the elementary level. Only one in five of the districts surveyed employ full-time science supervisors/coordinators, while two in five have none. Moreover, about one-fourth of the principals in any grade range consider themselves not well qualified to supervise science instruction.

The greatest single concern of almost everyone in education is for greater financial support. Science teachers consider inadequate facilities, insufficient funds for equipment and supplies, and lack of materials for individual instruction as their most serious problems.

Public school enrollments are dropping at all levels, but the percentage of students enrolled in science courses is at present relatively stable. However, the percentage taking high school chemistry and physics is very small.

Despite the many problems and conditions reported which teachers feel inhibit science teaching, individual teachers manage to eliminate many of these barriers. It is clear that successful science teaching is still primarily dependent on what the teachers do with their students.

THE TEACHER IS THE KEY

A Report on Three Studies by the National Science Foundation of the Status of Precollege Science, Mathematics, and Social Science Education

In 1976, in response to Congressional criticism of its precollege program, the National Science Foundation undertook to determine the state and needs of science, social studies, and mathematics education in this country. In order to acquire the information it sought, NSF awarded grants for three studies: (1) a survey of school administrators, supervisors, and teachers, conducted by the Center for Educational Research and Evaluation of the Research Triangle Institute, North Carolina, of which Iris Weiss was project director;¹ (2) a literature search by Stanley L. Helgeson, Patricia E. Blosser, and Robert W. Howe of the Center for Science and Mathematics Education at the Ohio State University;² and (3) a number of in-depth case studies conducted in a variety of school systems, directed by Robert E. Stake and Jack A. Easley of the University of Illinois-Urbana.^{3,4} This report will deal --briefly--with the findings of the three studies (published in 1978) which are of particular interest and importance to teachers teaching science--whether as a separate discipline in junior or senior high school, or as part of the curriculum in a self-contained elementary school classroom--and to science educators responsible for the education of these teachers.

The studies bring into focus current practices and conditions that affect science teaching. The findings are extensive and documented. Although most science teachers will find little of which they are not already aware, the studies do serve effectively to establish those local conditions, practices, and trends which are generally characteristic of schools nationwide. As a consequence, it will be easier for teachers and administrators to separate out those problems which, being locally derived, may be solved by local initiatives from those problems which stem from larger currents of societal, economic, and political conditions. The solution of the latter can be little affected by independent local efforts.

I. How Do Teachers Teach?

What is taught and how it is taught are two questions for which answers are very much interrelated. The major activities in science curriculum development in the 1955-75 period were funded by the National Science Foundation. The NSF-sponsored curriculum improvement projects presented science content compatible with the practicing scientists' view of science which required a teaching approach characterized by openness, flexibility, inquiry, and student involvement in more than just reading about science and watching demonstrations.

It is encouraging to report that the study found that there is more use of laboratory and hands-on instruction than was the case before the NSF curricula were developed and implemented. The NSF teacher institutes have also had an impact: 73 percent of the teachers who had attended one or more of the institutes arranged for their students to have hands-on experiences at least once a week, as contrasted with 42 percent of the teachers who had not attended. There has also been an increase in the use of student-centered classroom activities as a result of the institute program.

But despite the influence of the NSF-sponsored curricula and institutes, classroom observers reported that at all grade levels the predominant method of teaching was recitation (discussion) with the teacher in control, supplementing the lesson with new information (lecturing). The key to the information and the basis for reading assignments was the textbook.

Most questions were observed to be concerned with definitions and the acquisition of information and were mostly taken from the textbook. Classrooms in which individual thought, inquiry, and open discourse took place were observed but not frequently. Still less frequently did the teacher assume the role of a fellow learner.

The next most frequently observed activity was the demonstration, conducted in two out of five classes once a week or more. The number of classes using hands-on experiences once a week or more increases from one in three in elementary schools to three in four in senior high schools.

Student reports and projects are used once a month or more in half of the classes. Other teaching techniques such as field trips, guest speakers, simulations, contracts, programmed instruction, and similar programs are used once a month or more in less than 10 percent of the classes and are never used in 50 percent of the science classes surveyed, with the exception of field trips, which are never used in 31 percent of the classes. Time spent in various instructional arrangements does not differ significantly for the various grade levels. Approximately one-half of the time the entire class is arranged as a group, one-sixth of the time it is divided into small groups, and about one-third of the time students work individually.

In all of the schools surveyed, the national trend to make curricula more explicit and to make learning more measurable was evident. Schools had prepared or adopted statements of objectives and had developed criterion test items with which to determine student accomplishment of the objectives. In general, teachers and administrators reacted favorably to the manageability and clarity of the objectives-based system, but no evidence had been gathered by the schools surveyed to indicate that achievement levels of students had increased as a result.

II. What Do Teachers Teach?

What do these reports tell us about the science curriculum? Few, if any, surprises emerge. In senior high schools, year-long biology, chemistry, and physics courses still comprise the major part of the curriculum. Most states still require only one year of high school science and do not require any specific course.

The Dominant Textbook. The secondary school science curriculum is ordinarily organized with a textbook as its core; more than half the science teachers sampled in the survey reported that they used a single text, with approximately one-third indicating that more than one text was required for their courses. Texts are usually selected by individual teachers and teacher committees. Principals and supervisors are sometimes involved in text selection, but the survey indicates that parents, students, and school board members have little to say in this process, even though the text often defines a complete curriculum. Despite the media attention given to a few isolated instances, texts do not often generate controversies.

Some states have text-adoption procedures which require books purchased with state funds to be selected from an approved statewide list, but schools in these states often broaden their choices by using local funds when available. The texts themselves frequently reflect the influence of the curriculum projects developed with the support of the National Science Foundation during the 1960s, and this must surely be regarded as a significant residue of those efforts. Even though the choice of text is usually theirs alone, many teachers criticize the text they are using as having too difficult a reading level for many of their students.

Inquiry and Laboratory Methods. Survey data suggest that the domination of the curriculum by the textbook tends to discourage the use of inquiry techniques which require students to do more than look up information in the text and then recite or record it. In addition to reading and recitation, teachers report that workbook exercises provide much of whatever activity exists in typical classrooms. Even when teachers seek to use laboratory investigation and inquiry techniques, barriers such as inadequate time-blocks in the schedule, shared classrooms, and inadequate facilities and supplies tend to foster more passive, text-oriented approaches. While many teachers report that inadequate funding makes laboratory activity difficult, the surveys indicate that lack of student motivation and the demanding nature of inquiry teaching may be equally significant. Additional funds might ease some problems, but there is little evidence presented here that funds alone would be sufficient to create more vital programs, at least not in the amounts likely to be made available.

Curriculum Priorities. Even as scientific literacy programs for the majority of students essentially end after the tenth-grade biology experience, science itself is given relatively low priority within most secondary schools in comparison to English and social studies, in which specific courses are usually required subjects throughout

the student's high school experience. Curriculum efforts involving teachers from several science disciplines are rare in American high schools, although larger schools often have special elective courses in fields such as oceanography, environmental science, and earth science. In many schools, these courses are designed to motivate students who would not ordinarily continue their study of science beyond tenth-grade biology, and thus represent commendable efforts to break away from more traditional patterns which have not succeeded in reaching many students.

One of the major impressions conveyed by the survey is that teachers of science courses for college-bound students have succeeded in preserving the elite characteristics of these courses for the small student populations that they serve. Many schools have tracking systems which have created alternative courses with less demanding requirements for students who are either not capable or are insufficiently motivated to deal with the material presented in traditional biology, chemistry, and physics courses.

Use of Community Resources. Community or other out-of-school curriculum resources are rarely used by science classes. The Case Studies, in particular, make abundantly clear that most schools (and science programs) are insular and removed from the mainstream of community activity. For example, when the schools of Columbus, Ohio, were forced to close during the winter of 1977 because of a fuel shortage, community resources were used only in a perfunctory way to continue the education of children, primarily because of inadequate planning and lack of experience in coping with the inevitable difficulties encountered in developing a curriculum organized around unfamiliar resources.

The Learning Environment. The report suggests that science classrooms in many schools do not provide stimulating surroundings. Of course, many individual teachers have made valiant efforts to deal with problems caused by inappropriate texts, poorly prepared and motivated students, lackluster administrations, and the like. Nevertheless, the broad picture that emerges of the nation's secondary science curriculum is not encouraging, particularly when one considers the large number of students who do not continue in science beyond the tenth grade.

Even though the barriers encountered by teachers seeking to develop responsive science programs are high, there appear to be enough successes to encourage others to try. Moreover, the surveys suggest that the decentralized system of American education provides considerable latitude to teachers who wish to modify the curriculum in response to the special needs of their students and communities. When one views the constrictive character of ministerial control of education in some other countries and the inhibiting effect which this control has on their systems, one has reason to be grateful once again for the vision of the Founding Fathers.

Junior High Science. Even though life science has become a standard course in many schools, general science is still the only

course taught in more than half of the junior high schools surveyed. However, physical and earth science programs are not uncommon. The survey suggests that the process of socialization constitutes an important educational objective in the junior high. Laboratory handouts, for example, sometimes list guidelines for appropriate classroom and laboratory behavior in addition to instructions for carrying out a laboratory activity. To some extent, the socialization objective may (but need not) inhibit inquiry and investigative approaches to learning; many may view it as unfortunate that schools have turned away from inquiry approaches in favor of text-dominated courses which stress knowledge acquisition, often by rote methods.

Elementary School Science. On the basis of the survey data, elementary school science must still be regarded as a significant problem area. Much of the difficulty stems from the fact that science in the elementary schools, not regarded as basic, is given a low priority in comparison to reading, mathematics, social studies and health. Most elementary school teachers and, presumably, their school administrators see little relationship between science and other areas of the curriculum, a perception that existed even before the recent emphasis upon basic education.

Elementary school science, like that in junior and senior high schools, is taught primarily by lecture and recitation based on one textbook. Elementary schools invest only a very small portion of their budgets in curriculum materials; science, perceived as of low priority, usually fares badly in the competition for scarce funds. As a result, most of the nation's elementary schools are inadequately equipped to provide a significant investigative laboratory experience to children. One of the more pessimistic findings of the surveys was that "fewer than half of the nation's elementary school children are likely to have even a single school year in which their teachers will give science a significant share of the curriculum and do a good job of teaching it."

The Curriculum—A Subjective View. A reader of these studies may conclude that the science curriculum is responding ponderously, at best, to changing social conditions, individual needs, developmental patterns of students, and perceptions of community and political realities. The curriculum cannot be considered in isolation from the setting in which education takes place, but it may be useful to make some brief subjective comments on the curriculum considered in a somewhat more limited sense: on the materials, practices, and perceptions described in the studies.

It appears that many science courses include material which is inappropriate for most of the students studying at that level. For example, high school biology courses often contain substantial amounts of biochemistry and molecular biology, even though the majority of biology students have not yet studied chemistry. It is true that these portions of the text are not studied by all students, but one is left with the impression, nevertheless, that many students are asked to spend a significant amount of time memorizing complex

details of biochemistry and molecular processes even though most have neither the necessary access to experimental evidence nor the reasoning skills needed to follow the intricate conceptual arguments. In a similar manner, chemistry courses are likely to be replete with rote representations of quantum mechanical models of atoms and molecules.

One can speculate that many school science programs may be strongly influenced by unrealistic perceptions of what colleges expect high school graduates to know, with the result that students are required to study material which they cannot understand in any significant way and which is unrelated to their current interests on the grounds that the material will be needed later. By now, it is painfully obvious that for most "later" never arrives.

In summary, some readers will conclude that one of the major inferences that can be drawn from these reports and case studies is that much of the secondary school science curriculum is mismatched to the interests and needs of the majority of students in our schools who will not pursue scientific or technological careers. In the current political setting of American education, characterized by declining enrollments, resource shortages, and unrealistic social expectations of schools, the inappropriateness of the curriculum may contribute heavily to the frustration of teachers, the malaise of students, and the dissatisfaction of parents. Those whose interpretation of these reports leads them to arrive at such a conclusion may well expect policy makers, teachers, and citizen groups to reexamine the content of the school science curriculum to ensure that it is responsive to the needs of contemporary America.

Of course, readers' impressions derived from the reports of site visitors and the results of questionnaires are inevitably influenced by their subjective views of the schools, science, and the way in which children learn. Citizens, science teachers, and policy makers at all levels need to know more about what is being taught, and whether the curriculum is, in the main, appropriate for the students to whom it is presented, taking into account their previous preparation and motivation. How well is science being taught? Do the methods convey something of the spirit of science? Is the tentative nature of science made clear? Do our science classes foster inquiry and scholarship? Quality assessment is always a sensitive matter, but these are the issues which we must engage, whether individually as teachers or collectively as faculties.

III. How Are Teachers Educated?

The studies contain information on the background and education of the teachers in the sample populations that point to some reasons for concern. While each state sets minimum requirements for science teachers, state certification criteria still do not reflect those proposed by professional associations, which call, particularly, for more science content. This is especially crucial in the elementary and junior high schools, where most of the science instruction occurs.

It is at these levels that teachers have the least adequate science content preparation and the poorest physical facilities, while at the same time the fewest certification programs are available to them. Secondary teachers fare better: Only slightly more than one-tenth of them are currently teaching one or more science courses for which they feel inadequately qualified. On the other hand, 16 percent of the elementary school teachers surveyed feel "not well qualified" to teach science, and less than a quarter of them feel "well qualified" to do so. This feeling of inadequacy by elementary teachers to handle science instruction permeates all three studies and indicates a need for some serious work by all those who can help alleviate this problem.

Reactions to the inadequacy of preservice education for science teachers was mixed. The Case Studies indicated some low estimates of the quality of education courses and a concern by observers that many science teachers leave college with so little command of the substantive content of the NSF-initiated curricula that they are in need of remediation at the instant they graduate. In addition, teachers feel threatened by the pressure for accountability and the "back-to-basics" movement for which they were not prepared in their preservice training.

It is discouraging to note, too, that knowledge of science is rarely considered basic by the state boards of education, and science education is rarely included in state needs statements. This in itself may be indicative of a low interest by the general public in supporting high-quality science instruction.

Improved science teacher education, both pre- and inservice, is an important need. While continuing research in science teaching/learning is vitally needed, the results of that research need to be better communicated and applied in both the preservice and inservice programs. One of the studies' observations is that there is a critical need for preservice and inservice science education to be viewed and dealt with as a continuous program rather than as discrete entities handled by two different sets of people. This presents a challenge to the teacher-training institutions not only to do appropriate follow-up studies on their graduates but to work even more closely with the school districts that employ them.

Although the studies seem to indicate that today's secondary school science teachers are better educated than were those of the 1950s, both the teachers' perceptions and the findings of research indicate that there is still a critical need for inservice education. Approximately half of the elementary science teachers and more than 41 percent of the secondary science teachers had taken a course for college credit in 1976-77. Sizable numbers of teachers have earned one or more degrees beyond the bachelor's: more than half of the secondary school science teachers and just over a quarter of the elementary science teachers. However, since little of this graduate study by elementary teachers is done in academic science courses, there is a pressing need for both preservice and inservice training

to overcome their fear of teaching science, that they may teach it well and with enthusiasm.

A consistent theme throughout all the documents was the high value ascribed to NSF-sponsored activities in the education of science teachers. The most frequently attended programs were the NSF Summer Institutes: approximately two-thirds of the state science supervisors and almost 40 percent of the 7-12 grade science teachers surveyed had participated in one or more of these. Unfortunately, less than a fifth of the elementary science teachers had done so.

The second most often attended activity reported was the In-Service Institute, with participation by 18 percent of the 7-12 grade science teachers and 10 percent of the elementary teachers. While the overwhelming evidence is that these government-supported programs were considered to be of major help to science teachers, the majority of teachers currently teaching have not participated in them. This fact should be carefully noted and appropriate action taken. It is absolutely essential that elementary teachers be given continuous in-service and supervisory consultant help in science and in the teaching of science since their education does not include any significant study in these two areas.

IV. Who Helps the Teacher?

Most school districts have in print coordinated sequences of courses. But teachers critical at each grade level of their students' previous learning deviated from the syllabus as they saw fit. The lack of articulation in science curricula between grades, within schools, and between different schools at the same level is a significant finding. Individual teachers--within broad limits--select the content and methods which they believe appropriate, but the study found that teachers were more on their own than they wanted to be. The need for leadership in coordinating and directing individual teacher's efforts and initiatives toward common goals was apparent but unfilled.

Federal and state offices and legislation which have increased administrative duties, and local opposition to increasing school costs have fostered the trend both to decrease the number of central administrative offices and to redirect their efforts from "pedagogical matters to management matters." Decentralization of authority has moved some of the management problems to building principals, leaving them less time to work with teachers in developing and implementing the educational program. The study found that only one in five of the districts surveyed employed full-time science supervisors/coordinators and that two in five of the school districts had none.

In the schools, instructional help and leadership for teachers can come from the school principal and/or supervisory personnel. The study found that about one-fourth of the principals in any grade range felt that they were "not well qualified" to supervise science

instruction. The percentage of department chairmen found in the schools decreased from a high of 74 percent in senior high school to a low of 27 percent in the primary grades. Chairmen who received additional compensation increased from a low of one in ten in the primary grades to one in two in senior high schools.

Teachers who had consultant and supervisory help were more satisfied than those who had to work more or less on their own. Elementary teachers, especially, receive little supervisory, consultant, and leadership support in teaching science, although they are most comfortable when such support is available. The studies found also that candidates for elementary teacher certification are "seldom required to take more science content than that required for the general education component of their undergraduate program." Thus teachers who are least well prepared to deal with the teaching of science are given the least assistance.

More and more, two separate systems--management and instructional--are developing within the schools and are interacting less and less. The management system absorbs the energies and time of administrators at both the central administration and individual school levels. The instructional system functions through the efforts of individual teachers working largely without leadership and direction except in those few instances where curriculum and supervisory personnel are available. The need is evident. The absence of curricular and supervisory direction is subject to local attention and correction by local schools' initiatives. The development of an effective science program requires constant attention, leadership, and support; it cannot be left to develop by chance through the unorganized and undirected efforts of individual teachers regardless of how excellent these individual efforts may be.

V. With What Do Teachers Teach?

The individual classroom teacher still determines the primary mode of instruction in most classrooms, with the textbook the primary tool. Less than 10 percent of the schools have used practices such as modular scheduling or television instruction. Nor do the majority of teachers at any grade level consider computers or computer terminals necessary. Similarly, most science classes do not use cameras. While less than 15 percent of science classes make use of greenhouses, almost 40 percent would use them if they were available. Almost identical figures were given for the use of weather stations. Microscopes and scientific models, on the other hand, are widely used. Almost 30 percent of K-3 science classes use microscopes; while an additional 20 percent would like to have them. Usage goes up to more than 60 percent in the fourth grade and remains at least that high through all of secondary school. Even though a third of 10-12 grade classes use calculators, only a tenth of junior high school classes use them, and only about 2 percent of elementary schools report any calculator usage.

Financial Needs. Although little information was collected about the financial support of science instruction, that which was gathered is worth sharing. The greatest single concern of almost everyone involved in education is the need for an improved program of financial support. While the percentage of financial support for the schools from federal and state sources has increased since 1955, federal support for science education has declined since the late 1960s. Since state support tends to follow federal trends, state support for science education has also declined and is likely to continue to do so.

At the time of the study (1977), the average per pupil expenditure in school districts across the nation was \$1,246. A recurring note in the Case Studies was that increasing energy costs and frequent voter rejection of special school levies were reducing funds available for the school science program. Relatively few schools have specific budgets for science equipment and supplies. In general, schools are more likely to have specific budgets for science supplies than for equipment, and secondary schools are significantly more likely than elementary schools to have specific budgets for both.

A sizable number of school districts--over one-third--did report receiving funds in 1975-76 from the National Defense Education Act for facilities, equipment, and supplies used in science instruction, and one-fourth got similar funding from the Elementary and Secondary Education Act in the same school year. On the other hand, only a very small number of school districts received science instruction funding from other government grants, specific state grants, private foundations, or parent organizations.

Teachers considered inadequate facilities, insufficient funds for purchasing equipment and supplies, and lack of materials for individual instruction as the three most serious problems affecting science instruction. More than half of them wanted money to buy supplies on a day-to-day basis. This is an appropriate request that could be accommodated within the limits of existing financial support if administrators and teachers would work cooperatively toward a solution.

Inadequate student reading abilities and lack of teacher planning time were also considered as serious problems by teachers, and many of them felt that the major area that needed improvement was in the availability of laboratory assistants or paraprofessional help. Insufficient time to teach science was considered more of a serious problem in the lower than in the upper grades.

VI. Whom Do Teachers Teach?

Accurate enrollment figures are typically difficult to get, but the studies do furnish us with some general information and with what may be a discouraging note. While enrollments in public elementary

schools were increasing from 1955-1969, class sizes during that period were reduced. During that same period, secondary school enrollments also increased, as did the percentage of students enrolled in science courses. That percentage has remained relatively stable. Enrollments, however, are now beginning to decline, with elementary enrollment declining more rapidly than secondary. Public school enrollments, particularly, have dropped considerably in some areas where integration and consolidation of schools have led to the emigration of substantial numbers of students to private and church-related schools. Inevitably, just as the increasing enrollments had an impact on schools, the decreasing enrollments will have an impact, especially financially.

Despite the fact that the percentage of secondary school students taking science courses has not decreased, it is nevertheless true that the percentage taking chemistry and physics is very small. It seems likely that one reason these numbers are so small is that only 21 percent of the states require more than one year of science in grades 9-12. For the great majority, that one year is tenth-grade biology, with fewer than half advancing into chemistry. The attrition becomes even more severe in physics, with fewer than half of the nation's chemistry students going on in that fundamental discipline.

VII. Do Teachers Count?

Almost all elementary school science is taught by teachers in self-contained classrooms. Secondary science classes are taught more often by special science teachers. The studies found, not surprisingly, that within any classroom the science taught and the way it is taught is dependent primarily on what the individual teacher believes, knows, and does. Numerous studies indicate that the type of instruction does affect student learning and that the teacher is the most important instructional variable. The critical role of the teacher in instituting changes in science teaching is well documented.

Changes in science teaching nationwide are simply the summations of changes in individual schools functioning independently with or without strong and inspired local initiatives or leadership. Any movement to change science teaching and learning will require the wholehearted support, cooperation, and creative involvement of teachers as partners. This speaks for more effective organizational patterns in the schools in which the talents and ideas of teachers are harnessed and directed by knowledgeable school leaders. It also means a willingness on the part of teachers and administrators to be flexible and empirical in considering new content, methods, and goals.

The continuing rejuvenation of science content and teaching methods in response to new findings and societal goals requires access to and utilization of the national wisdom. Otherwise, local initiatives will amount to little more than stirring the pot! Large-scale infusions of curriculum innovations such as the NSF-sponsored projects are valuable in that they provide materials which no school district could develop on its own. The continued availability of

such materials is essential to the growth and improvement of the science education enterprise in the United States. Indeed, most superintendents felt that federal support for continued curriculum development was essential (66 percent) and that NSF should help teachers learn how to use the new curricula (77 percent). Implementation of new materials can only take place at the local level and then only if teachers are prepared and willing to use them.

Since so much depends on the teachers, it becomes necessary to focus attention there. Unfortunately, the study found that many teachers feel they have little power to change things, see little more they can do themselves, and are resigned to the status quo. Many problems and conditions which teachers feel inhibit science teaching were reported. The fact is that many of these obstacles--such as insufficient background in science, lack of equipment, inadequate room facilities, and insufficient time--can be eliminated or at least attenuated if teachers will refuse to accept them as barriers. Teachers must assume more responsibility for creating conditions which will enhance their efforts in the classroom. This may seem to be an unreasonable expectation to teachers enmeshed in the demands of each day's teaching, but teachers and administrators within individual schools must find ways to provide time for unhurried thought and deliberate planning. Total and final responsibility for what happens in science teaching does not rest solely on the shoulders of teachers, but a successful school program in science education is solely dependent upon what they do with their students. Unmistakably, the teacher is the key!

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